

Award Number: W81XWH-15-2-0085

TITLE: Evaluation of Role 2 (R2) Medical Resources in the Afghanistan
Combat Theater: Past, Present and Future

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REPORT DATE: October 2016

TYPE OF REPORT: Annual

PREPARED FOR: U.S. Army Medical Research and Materiel Command Fort Detrick,
Maryland 21702-5012

DISTRIBUTION STATEMENT:

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REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
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1. REPORT DATE (DD-MM-YYYY) October 2016		2. REPORT TYPE Annual		3. DATES COVERED (From - To) 30 Sep 2015 - 29 Sep 2016	
4. TITLE AND SUBTITLE Evaluation of Role 2 (R2) Medical Resources in the Afghanistan Combat Theater: Past, Present and Future				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER W81XWH-15-2-0085	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) COL Elizabeth Mann-Salinas, PhD, RN				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) The Geneva Foundation 917 Pacific Ave., Ste. 600 Tacoma, WA 98402				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) US Army MPMC Ft Detrick, MD 21702-5012				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT This observational study will be devoted to the analysis of existing (retrospective) data as noted in detail above. The data used for this study will be extracted from the Joint Theater Trauma System (JTTS) R2 Registry, which has been in place since 2008 and allows data collection at levels of medical care that previously did not have full trauma registry capabilities in Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and Operation New Dawn (OND). Aim 1: A retrospective review of all available data in the R2 Registry (n = approximately 15,000 records) will be conducted to evaluate combat casualty care using descriptive statistical analysis and modeling techniques. Aim 2: Identify the ideal provider training and competency assessment, sustainment and evaluation for medical staff (physicians, nurses, other licensed professionals, medics) deployed to the R2 environment.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Unclassified	18. NUMBER OF PAGES 66	19a. NAME OF RESPONSIBLE PERSON USAMPMC
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (include area code)

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Introduction:

There exists a continued lack of evidence about the impact of Role 2 (R2) medical resources in the combat theater. Although a R2 registry has been in place since 2008, no systematic evaluation for these data has been conducted. Without analysis of this information, military planners and medical leaders will be unable to best allocate R2 resources in future operations. Furthermore, the clinical competencies required for each medical team member to function optimally in this environment have yet to be clearly defined or systematically supported across the Tri-Services.

Keywords:

Role 2 (R2)

Role 3 (R3)

Combat Casualty Care (C3)

Role 2 Registry (R2R)

Department of Defense Trauma Registry (DoDTR)

Operation Enduring Freedom (OEF)

TACEVAC

Accomplishments:

What were the major goals of the project?

CY15 Goals – Initiate R2 Registry (R2R) analysis and conduct comprehensive review of training literature, individual experiences, and Tri-Service training resources.

- Describe all data available in R2R, conduct gap analysis.
- Compile and analyze all “lessons learned” regarding R2 operations during OEF and OIF.
- Describe all training assets available for R2 team members.
- Conduct survey of deployed R2 members for personal training experience, confidence upon deployment.
- Based on literature review, recommend best practice for R2 training.

CY16 Goals – Develop R2R Performance Assessment Dashboard.

- Create metrics to evaluate R2 outcomes and team performance.
- Develop DoDTR report for near-real time feedback to deployed teams.
- Track training and sustainment programs for R2 members.

What was accomplished under these goals?

For this reporting period describe:

1) major activities

a. Identified OEF databases and described elements:

i. Joint Trauma Systems

- 1 DoDTR (n=x; pending data from JTS)
- 2 R2R (n=12,849)
- 3 Linked US patients from R2R and DoDTR (n=931)

ii. Golden Hour Database (TACEVAC, DoDTR, and AFME)

iii. TACEVAC Registry (n=9033)

iv. United Kingdom Joint Theater Trauma Registry (n=x; CRADA in place, pending data analysis)

v. Unit specific databases

- 1 59th Medical Wing Aeromedical (AE) and Critical Care Air Transport Team (CCATT) database
- 2 160th SOAR Pararescue Team registry

- b. Identified source of data from recent conflict in Iraq
 - i. Iraq Data from LTC Christina Hahn (July 2015- 2016; N=314; All Iraqi; All ground transport) and entered into a Role 2 Registry shell; analysis underway
 - ii. Lessons learned from LTC Hahn's experience provided to CDID Combat Developers and logistic packs will be tested in upcoming AWA 17 exercise OCT 2016
- c. Created the following protocols to answer specific aims:
 - i. H-15-010 "Evaluation of Role 2 (R2) Medical Resources in the Afghanistan Combat Theater: Past, Present and Future" (IRB Approved)
 - ii. H-16-009 "Analysis of Medical Interventions in the Combat Environment Related to Deployed Hospital Care" (IRB Approved)
 - iii. H-16-022 "Evaluation of Healthcare Systems Training for Combat Casualty Care Skills" (Pending IRB approval)
 - iv. H-16-023 "The Role 2 Experience: Comparing the Joint Trauma System Role 2 Registry and Surgeon Case Logs from 2008 to 2016" (Pending IRB approval)
- d. Collaborated with Subject Matter Experts to identify areas of interest and available datasets:
 - i. Created Transport Timing Working Group with experts and researchers from Army, Air Force and Navy to coordinate efforts and reduce redundancy in efforts
- e. Created standard white paper template for Role 2-related efforts and initiated the following white papers:
 - i. Burn
 - ii. Traumatic Brain Injury
 - iii. Pediatric
 - iv. Orthopaedic
 - v. Case Fatality Rate/ Died of Wounds Rate
 - vi. Combat Mortality Index
 - vii. Tourniquet Use
 - viii. Role 3 Utilization
- f. Collaborated with the following Vendors:
 - i. IVIR
 - 1 Description of Tri-Service trauma training courses (n=135), systematic literature review best practices (n=140)
 - 2 Development of recommended training program underway
 - 3 Gap analysis for each service underway
 - ii. VNIP
 - 1 Development of evidence based practice competency development and assessment tools for combat casualty care skills
 - iii. VMASC
 - 1 Development of Validated Trauma Knowledge Assessment Instruments for Role 2 and Role 3 Capabilities: Adult Nursing and Medical /Surgical Care
- g. Completed the following site visits to identify the current training:
 - 1 Rush University - Chicago, IL
 - 2 Strategic Operations (STOPS) – San Diego, CA
 - 3 Virginal Modeling and Simulation Center (VMASC) – Suffolk, VA
 - 4 Navy Trauma Training Center (NTTC) – Los Angeles, CA

- 5 Air Force C-STARs – Cincinnati, OH
- 6 NASA – Houston, TX
- 7 Army Trauma Training Directorate, - Miami, FL
- 8 Mayo Clinic, US Army Reserve TEAM STEPPS Training – Rochester MN
- 9 Army Warfighter Assessment (Forward Resuscitative Surgical Team) - Fort Bliss

- h. Created map of Afghanistan and geo-located all Role 2 units based on global positioning location to determine distance from regional Role 3 facilities

2) Specific objectives:

a. Aim 1:

- i. Describe all types of R2 assets
- ii. Describe epidemiology of patients treated at R2 facilities in OEF Regional Command (RC)-Southwest, then RC-South, then RC-East
- iii. Describe interventions performed
- iv. Identify and describe the characteristics of each R2 unit
- v. Describe volume of patients
- vi. Describe continuum of care from injury

b. Aim 2:

- i. Conduct a comprehensive inventory and description of current R2 pre-deployment training programs and individual experiences.
- ii. Perform a systematic review of the literature and military centers for lessons learned to describe evidence-based training and sustainment programs for medical provider C3 competencies.
- iii. Describe how competencies, training, sustainment differ among R1, R2, and R3.
- iv. Compare pre-deployment training for Active Duty versus Reserve members/teams
- v. Define the ideal sustainable training and sustainment program for C3 competencies.
- vi. Develop evidence-based tools and metrics to evaluate C3 competencies (individual and team).
- vii. Develop and validate a comprehensive Tri-Service C3 competency development and sustainment program.

3) Significant results or key outcomes, including major findings, developments, or conclusions (both positive and negative); and/or

- a. Role 2 Registry is more complete than the TACEVAC and DoDTR registries for events occurring at Role 2
- b. Limited ability to link patients in the R2R to the DoDTR (only able to link US)
- c. Aim 2 objectives related to training and competency directly support the newly forming Committee on Surgical Combat Casualty Care (CoSCCC) and will jump-start that committee into developing a core combat-related knowledge content for the DoD trauma training courses
- d. Initial review of the epidemiology of Role 2 experience as recorded in the R2 Registry published in Journal of Trauma
- e. Formal collaboration with the Israeli Defense Force and United Kingdom Ministry of Defense through CRADA agreements. Joint publications with both militaries in press

4) Other achievements. Include a discussion of stated goals not met.

- a. VNIP implemented clinical transition framework (CTF) in the emergency department and maternal child health unit to demonstrate applicability of competency framework in multiple clinical settings.
- b. VNIP completed Pilot of the CTF (satisfaction survey)

What opportunities for training and professional development has the project provided?

- VNIP Preceptor Training and Continuing Education Units
- MHSRS Continuing Education Units
- TSNRP Continuing Education Units

How were the results disseminated to communities of interest?

Results from this proposal were disseminated to:

- Journal of Trauma (in press)
 - Evaluation of Role 2 (R2) medical resources in the Afghanistan combat theater: Initial review of the joint trauma system R2 registry
- Military Medicine (in press)
 - The Afghan Theater: A review of Doctrine for Forward Surgical Treatment Facilities from 2008 to 2014
- Shock 2016 (in process)
 - Impact of Tourniquet use on mortality and shock for patients arriving at U.S. Role 2 surgical facilities in Afghanistan
- MHSRS 2016
 - Burn Nurse Competency Initiative in Support of Combat Casualty Care
 - Analysis of pediatric trauma in combat zone to inform high-fidelity simulation pre-deployment training
 - Point of Injury to Role 2 medical treatment facility: pre-hospital transport of casualties in Afghanistan
- Tri-Service Nursing Program 2016
 - Evaluation of elapsed time and mode of transportation from point of injury to Role 2
 - Evolution of an evidence-based competency assessment program for nursing specialty nursing
- Trauma and Acute Care Surgery Supplement
 - Analysis of Injury patterns in US and Israeli militaries as a strategic predictor of combat casualty care in future conflicts
- IMSH 2017 (submitted/pending)
 - Pediatric Role 2 and 3 Intervention and Medical Education Simulation (PRIMES) study
- AAST 2016
 - Combat Mortality Index (CMI): An early predictor of mortality in combat casualties
 - Mortality from Combat-related Traumatic Brain Injury (TBI) is best predicted by the Military Injury Severity Score (mISS)

What do you plan to do during the next reporting period to accomplish the goals?

- CY17 Goal – Expand R2 database to all deployed units to OEF/OIF.
 - Obtain all identified data other than R2R.
 - Create repository within DoDTR for these data.
 - Conduct analysis and contrast by R2 unit and phase of conflict (entry, surge, and sustainment).

- Collaborate with Committee for Surgical CCC to develop core training platforms and content for CCC
- Continue analysis of data to address US-UK mutual goals

Impact

What was the impact on the development of the principal discipline(s) of the project?

Nothing to Report

What was the impact on other disciplines?

Nothing to report

What was the impact on technology transfer?

Nothing to report

What was the impact on society beyond science and technology?

Nothing to report

Changes/Problems

Nothing to report

Changes in approach and reasons for change

N/A

Actual or anticipated problems or delays and actions or plans to resolve them

N/A

Changes that had a significant impact on expenditures

N/A

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

N/A

PRODUCTS:

Journal publications:

1. Evaluation of Role 2 Medical Resources in the Afghanistan Combat Theater: Initial Review of the Joint Trauma System Role 2 Registry”, Elizabeth A. Mann-Salinas, PhD; Tuan D. Le, MD, DrPH; Stacy Shackelford, MD; Jeffrey Bailey, MD; Zsolt T. Stockinger, MD; Mary Ann Spott, PhD; Michael Wirt, MD, PhD; Rory Rickard, PhD, FRCS; Ian Lane, BDS; Timothy Hodgetts, PhD, FRCP; Sylvain Cardin, PhD; Kyle N. Remick, MD; Kirby R. Gross, MD; in press *J Trauma and Acute Care Surgery*
2. The Afghan Campaign: A review of Extant Doctrine for Combat Casualty Care, Ian Lane, BDS, Zsolt Stockinger, MD, Stephen Bree, FRAP, Kirby Gross, MD, Jeffrey Bailey, MD, Samuel Sauer, MD, Timothy Hodgetts, FRAP, Elizabeth Mann-Salinas, PhD, RN; in press *Military Medicine MHSRS Supplement*

3. The Military Injury Severity Score (mISS): A Better Predictor of Combat-Mortality than Injury Severity Score (ISS), T Le, J Orman, Z Stockinger, MA Spott, S West, E Mann-Salinas, K Chung, K Gross, in press J Trauma MHSRS Supplement
4. Analysis of injury patterns and roles of care in US and Israel militaries during recent conflicts: two are better than one, B Antebi, PhD; A Benov, MD, MHA; E Mann-Salinas, PhD, RN; T Le, MD, DrPH; A Batchinsky, MD; L Cancio, MD; J Wenke, PhD; H Paran, MD; A Yitzhak, MD; B Tarif, MD, MHA; K Gross, MD; D Dagan, MD; E Glassberg, MD, MHA, in press, J Trauma MHSRS 2015 supplement

Books or other non-periodical, one-time publications

Nothing to report

Other publications, conference papers, and presentations

1. "Evaluation of the Joint Trauma System Role 2 Registry to Inform Provider Pre-Deployment Readiness", EA Mann-Salinas, T Le, Jeffrey A Bailey, MA Spott, ZT Stockinger, MD Wirt, R Rickard, KR Gross, 2015 Military Health System Research Symposium, Ft Lauderdale, FL 17-20 August 2015
2. Analysis of Injury Patterns in US and Israeli Militaries as a Strategic Predictor of Combat Casualty Care in Future Conflicts", B Antebi, A Benov, T Le, EA Mann-Salinas, J Orman, J Wenke, A Cap, E Glassberg, A Yitzhak, B Tarif, K Gross, D Dagan, 2015 Military Health System Research Symposium, Ft Lauderdale, FL 17-20 August 2015
3. "Preparing Nurses for Future Combat Operations: Evaluation of the Role 2 Registry to Inform Pre-Deployment Training", EA Mann-Salinas, T Le, Jeffrey Bailey, MA Spott, MD Wirt, KR Gross, 2015 Triservice Nursing Research Program Research and Evidence Based Practice Dissemination Course, San Antonio, TX 31 August – 3 September 2015
4. Development of a Program to Improve Evaluation of Burn Nursing Competencies", KK Valdez-Delgado, S Boyer, MG Barba, AL Kuylen, DJ Flores, PB Colston, EA Mann-Salinas, 48th Annual American Burn Association Meeting, Las Vegas, NV 03-06 May 2016
5. Analysis of Pediatric Trauma in Combat Zone to Inform High-Fidelity Simulation Pre-deployment Training", PT Reeves, TD Le, EA Mann-Salinas, JM Gurney, ZT Stockinger, MA Borgman, 2016 Military Health System Research Symposium, Kissimmee, FL 15-18 August 2016
6. "Evolution of an Evidence-Based Competency Assessment Program for Specialty Nursing", KK Valdez-Delgado, MG Barba, A Kuylen, DJ Flores, S Boyer, PB Colston, JJ Melvin, EA Mann-Salinas, 2016 Tri-Service Nursing Research and EBP Dissemination Course, San Antonio, TX, 22-25 August 2016
7. "Impact of Tourniquet use on Mortality and Shock for Patients Arriving at U.S. Role 2 Surgical Facilities in Afghanistan", T Le, JF Kragh, M Dubick, K Gross, J Bailey, J Orman, Z Stockinger, EA Mann-Salinas, 2015 Military Health System Research Symposium, Ft Lauderdale, FL 17-20 August 2015
8. "Capability-based Systems of Care in Israel Defense Forces and US Army", A Benov, EA Mann-Salinas, T Le, B Antebi, E Glassberg, A Yitzhak, B Tarif, K Gross, D Dagan, 2015 Military Health System Research Symposium, Ft Lauderdale, FL 17-20 August 2015
9. "Preparing Nurses for Future Combat Operations: Evaluation of the Role 2 Registry to Inform Pre-Deployment Training" EA Mann-Salinas, T Le, Jeffrey Bailey, MA Spott, MD Wirt, KR Gross, 2015 Triservice Nursing Research Program Research and Evidence Based Practice Dissemination Course, San Antonio, TX 31 August – 3 September 2015
10. "Impact of Tourniquet use on Mortality and Shock for Patients Arriving at U.S. Role 2 Surgical Facilities in Afghanistan" TD Le, JF Kragh, MA Dubick, JM Gurney, SA Shackelford, KR Gross,

JA Bailey, ZT Stockinger, EA Mann-Salinas, 39th Annual Conference on Shock, Austin, TX 11-14 June 2016

11. "Development of a Competency Assessment Program to Transition Military Medical Personnel to Specialty Practice ", KK Valdez-Delgado, MG Barba, A Kuylen, DJ Flores, S Boyer, P Colston, JJ Melvin, EA Mann-Salinas, 2016 Military Health System Research Symposium, Kissimmee, FL 15-18 August 2016
12. "Point of Injury to Role 2 Medical Treatment Facilities: Pre-hospital Transport of Casualties in Afghanistan", JD Trevino, TD Le, RS Kotwal, BW Tarpey, ZT Stockinger, KK Chung, EA Mann-Salinas, 2016 Military Health System Research Symposium, Kissimmee, FL 15-18 August 2016
13. "Evaluation of Elapsed Time and Mode of Transportation from Point of Injury to Role 2 ", JD Trevino, TD Le, RS Kotwal, BW Tarpey, ZT Stockinger, KK Chung, EA Mann-Salinas, 2016 Tri-Service Nursing Research and EBP Dissemination Course, San Antonio, TX, 22-25 August 2016
14. "Evolution of an Evidence-Based Competency Assessment Program for Specialty Nursing", KK Valdez-Delgado, MG Barba, A Kuylen, DJ Flores, S Boyer, P Colston, JJ Melvin, EA Mann-Salinas, 2016 Tri-Service Nursing Research and EBP Dissemination Course, San Antonio, TX 22-25 August 2016
15. "Combat Mortality Index (CMI): An Early Predictor of Mortality in Combat Casualties", TD Le, ZT Stockinger, JM Gurney, EA Mann-Salinas, SA Shackelford, KS Akers, KK Chung, KR Gross, 75th Annual Meeting of AAST and Clinical Congress of Acute Care Surgery, Waikoloa, HI 14-17 September 2016
16. "Mortality From Combat-Related Traumatic Brain Injury (TBI) is Best Predicted by the Military Injury Severity Score (mISS)", TD Le, ZT Stockinger, JM Gurney, EA Mann-Salinas, SA Shackelford, KS Akers, KK Chung, KR Gross, 75th Annual Meeting of AAST and Clinical Congress of Acute Care Surgery, Waikoloa, HI 14-17 September 2016

Website(s) or other Internet site(s)

<http://www.vnip.org/members/VNIPMilitaryMedicalSystems.html>

Technologies or techniques

Nothing to report

Inventions, patent applications, and/or licenses

Nothing to report

Other Products

- VNIP competency based orientation tool for SAMMC foundational nursing skills
- VNIP clinical coaching plans for emergency department and maternal child health
 - 10 emergency department
 - 14 maternal child health
- Transition in Practice Towards Optimal Performance (TIP-TOP) Tool Kit to support clinical competency development

Participants & Other Collaborating Organizations

What individuals have worked on the project?

- COL Elizabeth A. Mann-Salinas, PhD, RN; No change
- Vermont Nurses in Partnership (VNIP), Inc. (Susan Boyer); No change
- IVIR (Nadine Baez/Erin Honold); No change
- VMASC (Andi Parodi); No change
- Col Stacy A. Shackelford, MD; No change

- Tuan D. Le, MD, DrPH; No change
- Jennifer Trevino, MBA; No change
- Krystal Valdez-Delgado, BSN, RN; No change
- Nicole Caldwell, RN; No change
- COL Kirby Gross, MD; No change
- Col Jeff Bailey, MD; No change
- Brig Timothy Hodgetts, MD, No change
- Col Ian Lane, DDS; No change
- Surg Capt. Rory Rickard, MD; No change
- LTC (P) Kyle Remick, MD; No change
- COL John Oh, MD; No change
- David Cannon; No change
- Maj Avi Benov, IDF; No change
- LTC (P) Jennifer Gurney, MD; No change
- LTC Matt Borgman, MD; No change
- COL (Ret) Russ Kotwal, MD; No change
- CAPT Zsolt Stockinger, MD; No change
- Ben Antebi, PhD; No change
- Patrick Reeves, MD; No change
- Amanda Staudt, PhD, MPH; No change
- LTC Christina Hahn, MD; No change

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Nothing to report

What other organizations were involved as partners?

Organization Name: See list below

Location of Organization: See list below

Partners:

United Kingdom Ministry of Defense: Collaboration and personnel exchanges

Israeli Defense Force: Collaboration

Vermont Nurses in Partnership: Collaboration

Information Visualization and Innovative Research, Inc.: Collaboration

Virginia Modeling Assessment and Simulation Center, Old Dominion University: Collaboration

Rush University: Collaboration

Strategic Operations: Collaboration

Capability Development Integration Directorate: Collaboration

Army Medical Department Centers For Medical Lessons Learned: Collaboration

Special Reporting Requirements

Quad Chart:

Attached

Appendices

Attached:
Journal publications (4)
Role 2 Survey Question

Evaluation of Role 2 (R2) Medical Resources in the Combat Theater: Past, Present and Future

W81XWH-15-2-0085

PI: COL Elizabeth Mann-Salinas

Sponsor: JPC-6

Task Area: Systems of Care for Complex Patients
Org: USAISR/The Geneva Foundation
Award Amount: \$3,540,354



Purpose: Describe and understand impact of Role 2 (R2) utilization during OEF, with emphasis on patient outcomes and provider competency

Aim 1: Descriptive study of all available R2 Registry (R2R) information for combat casualties. Describe: 1) who – injuries treated; clinician mix and pre-deployment training received; 2) what – procedures, interventions, products; 3) why – who received operative intervention, justification for over-flight to R3; 4) when – dates; time from injury to R2, time spent at R2, R2-R3; 5) where – location of R2 relative to POI, R3; terrain; AE support/assets available; 6) how – outcomes associated with R2 utilization

Aim 2: Identify the ideal provider training and competency assessment for R2 medical team: 1) comprehensive description of current Tri-Service pre-deployment training programs; 2) systematic review of the literature to describe evidence-based training and sustainment programs for combat casualty care(C3) competencies; 3) define the ideal sustainable training and sustainment program for C3 competencies; 4) develop and validate a Tri-Service C3 competency development and sustainment program



Conducted 8 site visits in FY2016 to observe pre-deployment training; results summarized in a report for the CoSCCC of > 140 unique available MIL/CIV training programs for Active, Reserve and Guard medical professionals.

Timeline and Cost

Activities	CY	15	16	17	18	19
Role 2 data analysis: who, what , why, when, where, how						
Identify metrics and develop Performance Assessment Dashboard						
Develop evidence-based competencies for R2 team members						
Create program for achieving/sustaining competencies for Tri-Services						
Outcomes of Performance Assessment / Dashboard / training standards						

Budget (\$3.5M)	\$1.2M	\$880	\$640	\$472	\$286
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Updated: 25 October 2016

Products/Deliverables/Updates: Systematic review of all available training courses for pre-deployment readiness (n=135) and literature review (n=140) performed and results will be presented 8-9 DEC to Committee for Surgery in Combat Casualty Care (CoSCCC) . Four (4) manuscripts published in J Trauma/ MIL MED; six (6) podium and ten (10) poster presentations. Formal collaboration with United Kingdom Ministry of Defense and Israeli Defense Force. Successful pilot of competency tools conducted at BAMC (TIP-TOP); next step is formal validation project and integration within foundational clinical practice to support operational skill mastery.

Payoff/Outcomes for CCC: The efforts from this proposal directly support the newly formed CoSCCC. Ultimate outcome will be an evidence based standardized trauma readiness platform for all services. Combat developers will have data-driven evidence for improving forward surgical team utilization.

Plan Transition: To inform the CoSCCC on training and readiness; support Clinical Practice Guidelines; AMEDD Center for Medical Lessons Learned.

Comments/Challenges/Issues/Concerns: Outstanding progress during first year of this project. The alignment with the needs of the CoSCCC will save that committee at least 1 year of effort due to work accomplished under this project aims. No concerns or issues at this time.

Budget Expenditure to Date: Projected Expenditure: =\$1.2M; Actual Expenditure: =\$1M

Military Medicine MHSRS Supplement

The Afghan Theater: A review of Doctrine for Forward Surgical Treatment Facilities from 2008 to 2014

Ian Lane, BDS¹; Zsolt Stockinger, MD²; Samuel Sauer, MD²; Mark Ervin, MD³; Michael Wirt, MD, PhD⁴; Stephen Bree, FRAP⁵; Kirby Gross, MD⁶; Jeffrey Bailey, MD⁷; Timothy Hodgetts, FRAP⁸; Elizabeth Mann-Salinas, PhD, RN⁴

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⁴US Army Institute of Surgical Research, San Antonio, TX

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⁸Royal Center for Defence Medicine, Birmingham, UK

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Short Title: Afghan Campaign Doctrine

Disclosures:

The authors declare no conflicts of interest.

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense

Abstract

This paper forms part of a series that will explore the effect that Role 2 (R2) medical treatment facilities (MTF) had on casualty care during the military campaign in Afghanistan and how we should interpret this to inform the capabilities in, and training for future R2 MTFs. Key aspects of doctrine which influence the effectiveness of R2 MTFs include: timelines to care, patient movement capabilities, and medical treatment facility capabilities. The focus of this analysis was to review allied doctrine from the United States, United Kingdom and the North Atlantic Treaty Organization (NATO) to identify similarities and differences regarding employment of R2 related medical assets in the Afghan Theater, specifically for trauma care. Several discrepancies in medical doctrine persist amongst allied forces. Timelines to definitive care vary among nations. Allied nations should have clear taxonomy that clearly defines MTF capabilities within the combat casualty care system. The R2 surgical capability discrepancy between US and NATO doctrine should be reconciled. Medical evacuation capabilities on the battlefield would be improved with a taxonomy that reflected the level of capability. Such changes may improve interoperability in a dynamic military landscape.

Key words: Allied doctrine; military; combat casualty care

INTRODUCTION

This paper forms part of a series that will explore the effect that Role 2 (R2) Medical Treatment Facilities (MTF) had on casualty care during the military campaign in Afghanistan and how we should interpret this to inform the capabilities in, and training for future R2 MTFs. Roles of care refer to the increasing medical capabilities available for the combat injured. Generally, at the point of injury, combat life savers (soldiers trained to perform basic first aid) and trained combat medics apply Tactical Combat Casualty Care interventions to stabilize casualties and prepare for evacuation ¹. Role 1 represents unit-level care at a field medical station, where a Licensed Independent Provider can provide advanced airway management and possibly initiate fresh whole blood transfusion in preparation for evacuation to surgical support. R2 provides more robust medical resources than Role 1, and is the first level of care where damage control surgery and advanced resuscitation may be provided, but offers limited patient holding ability. R2 is the first MTF in the chain of evacuation, also referred to as Deployed Hospital Care (DHC). Role 3 is a deployed field hospital offering expanded surgical and imaging capabilities; patient holding duration is technically unlimited. Role 4 is a fixed facility that is in the home country of the deployed force or that of ally, and offers all medical and surgical specialties from acute care to long-term rehabilitation.

The focus of this analysis is to review doctrine to identify similarities and differences regarding employment of R2 related medical assets in the Afghan Theater specifically for trauma care. The scope is limited to NATO and US/UK joint and single Service doctrine, as the overwhelming majority of MTFs and evacuation assets in Afghanistan were from these two nations. A R2 Registry was implemented by the US Joint Trauma System (JTS) in 2008 so doctrine from 2008 to 2014 was reviewed.

What is military doctrine and how is it organized

Military doctrine is the expression of how the military operates, linking theory, history, experimentation, and practice. Its objective is to describe how to think not what to think. Yet, despite its centrality to military thinking, doctrine has been described ² as ill-defined, confusing and poorly understood. NATO's definition of doctrine ³, used unaltered by many member nations including the US Department of Defense, is:

'Fundamental principles by which military forces guide their actions in support of objectives. It is authoritative, but requires judgment in application'.

It goes on to say that

'policy, as agreed by the highest National Authorities, normally leads and directs doctrine, and that applied doctrine is necessary for effective coalition building'.

The UK follows this line stating ⁴ that *"Except where there is a specific need for national doctrine, the UK will adopt and employ NATO doctrine"*.

Military doctrine has been variously categorized but contemporary taxonomies tend not to align doctrine to a particular level of conflict or environment. The UK ⁵advocates four broad levels; philosophy, principles, practices and procedures. Describing the relationships between these levels as ⁶:

Philosophy is conceptual, enduring, pervasive and largely descriptive. It provides understanding. **Principles**, which are more specific, build upon the philosophical foundations to summarize that

*understanding. Both are likely to provide clearer context than faster-moving doctrine can, provided they are malleable. **Practices** describe the ways in which activity is conducted. **Procedures** link practices together. Both are intended to be prescriptive. Lower-level doctrine could change relatively rapidly and pragmatically, often from a bottom-up direction. However, practices and procedures should always be consistent with the higher-level philosophy and principles, which change only as a result of measured consideration, which is usually a top-down process.*

Using this template, **table 1** shows how the doctrine examined within this paper fits into the organizational hierarchy:

The key aspects of operational factors which influence the effectiveness of R2 MTFs:

- Timelines to care
- Patient movement capabilities
- Medical treatment facility capabilities

TIMELINES

Once injured, the principal factor that determines mortality, morbidity and residual disability is time to required level of medical care. This is true of all medical emergencies, but is of over-riding significance when dealing with surgical emergencies – particularly surgical control of hemorrhage in the combat setting. Hence, evacuation time is the major clinical driver dictating the type and location of medical assets in operations and conflicts, and timeliness in providing appropriate intervention to the wounded or ill is crucial. The provision of high quality early intervention has been shown to improve outcomes, while any delay either before care is initiated or between subsequent levels of care, will be deleterious to patient outcomes ⁷.

Allied Doctrine, AJP 4-10 (A) was the extant NATO doctrine for the whole of the period. Its principal medical planning timeline was the 1-2-4 hr principle:

Primary (definitive) Surgery ⁸ for critically injured patients within 1 hr of wounding. If this is not achievable then Damage Control Surgery (DCS) ⁸ should be available within 2 hrs followed by primary surgery within 4 hrs. ⁸.

Subordinate NATO publications have not provided further guidance. AJMedP-1 (Med Planning) recommends the planning of Medical support based on the consideration of “all factors” ⁹ but does not explicitly mention time and its effect on a casualty. AJMedP-2 (MEDEVAC, medical evacuation) provides categories for patient evacuation ¹⁰ (Priority 1 requiring immediate transfer, P2 within 24 hrs and P3 within 72 hrs) but only referred to clinical timelines when discussing forward MEDEVAC ¹⁰ and did not specify any timelines by which casualties should reach a level of care. STANAG (standardization agreement) 2087 ¹¹ contradicts AJMedP-2, prescribing a 2 hr evacuation time limit for urgent cases and 4 hrs for priority cases.

UK Joint Doctrine initially (up to Mar 11) was based on JWP 4-03 ¹² which prescribed the 1:2:4 hour principle, albeit subtly different to the NATO description:

rapid access to first aid and BATLS (battlefield advanced trauma life support)/BARTS (battlefield advanced resuscitation techniques and skills) resuscitation within 1 hr of wounding; access to surgical resuscitation (e.g., damage control surgery) for those who require it within 2 hrs of wounding; and primary surgery within 4 hrs of wounding.

It also recognized that when required by the unique operational environment the principle could be adapted accordingly. This was superseded by JDP 4-03¹³ which advocated a new clinical paradigm; 10(min)-1-2¹⁴ where:

bleeding and airway control for the most severe casualties should be achieved as soon as possible – ideally within 10 minutes of wounding. MEDEVAC assets should reach the seriously wounding with skilled medical aid within 1 hr of wounding at the latest. Casualties that require surgery or further resuscitation should, where possible, be in an MTF equipped for this within 2 hrs of wounding.

UK Army Doctrine¹⁵ advocated the 10-1-2 timeline to guide decision making regarding the configuration and location of the MEDEVAC and MTFs while recognizing the enduring utility of the 1-2-4 hr principle that focuses on the timeliness for casualty movement between DCS and Primary surgery. Both US Joint (JP4-10 2006¹⁶) and US Army (FM 4-02.2¹⁷ May 07) doctrine described patient precedence for evacuation as:

within 2 hrs for Urgent cases, within 4 hrs for Priority cases and within 24 hrs for Routine cases.

The US position changed¹⁸, however, following Congressional Interest in late 08 and 09 and resulted in changes for prehospital evacuation of:

1 hr for urgent and urgent surgical missions to appropriate medical care^{7,18,19}.

This was incorporated into the Army FM 4-02.2²⁰ in Jul 09 and remained extant in the Oct 11 version (ATTP 4-02)²¹, the Aug 13 version of FM 4-02²², and the Aug 14 version of ATP 4-02²³. In these later publications the guidance was that Urgent cases should be evacuated as soon as possible and within 1 hr, yet the “Urgent-Surgical” category does not specify time to surgical intervention²³. Priority cases remained as within 4 hrs and Routine as within 24 hrs. These changes were not made to the Joint Doctrine until the current version was published in 2012²⁴. Subordinate doctrine publications such as FM 4-02.25 (Employment of Forward Surgical Teams (Mar 03)) offered no further guidance regarding time lines to care. US Army doctrine is generally stated as implementing or being in consonance with the North Atlantic Treaty Organization (NATO) standardization Agreements (STANAG). The US Joint Medical Doctrine referenced ABCA (America, Britain, Canada, Australia/New Zealand) publications but no Allied documents²⁵.

In **summary**, there were differing doctrinal timelines in use over the Jan 08 to Oct 14 time period in the Afghan theatre of operations as described in **Table 2**.

In terms of what level of care should be reached within these timelines, NATO Doctrine explicitly states that it should be to definitive surgery, ideally within 1 hr but if not DCS within 2 hrs. The UK advocates skilled medical aid within 1 hr and surgery within 2 hrs. While the US started the campaign with a 2 hr guideline for evacuation of urgent cases without explicitly stating to what level of care. This was changed to 1 hr in Jul 09 with the addition of the statement to “appropriate medical care”^{18,19}.

Medical Evacuation (MEDEVAC)

Evacuation of casualties is a crucial part of the deployed Health Service Support system and requires specific medical personnel and assets. Time to care creates interdependency between evacuation, treatment and the theatre holding policy ²⁶; with each directly impacting the other if the standard of patient care is to be maintained. Thus patient movement is not simply a transportation task but is part of the continuum of care, and a medical responsibility.

NATO doctrine ^{8,10} advocates that a medical evacuation system should have the following capabilities:

- a. The ability to evacuate casualties to a MTF 24/7, in all weather, over all terrain and in any operational circumstances.
- b. The provision of the necessary clinical care throughout the journey
- c. The ability to regulate the flow and types of patients

Unlike the Roles used to describe MTFs, NATO doctrine ^{8,10} describes MEDEVAC, be it ground or air (Aeromedical Evacuation (AE)), in terms of where along the chain of evacuation it operates giving 3 main categories:

- a. **Forward MEDEVAC/AE** - Point of wounding to the initial MTF. This is required by operational circumstances to meet clinical timelines.
- b. **Tactical MEDEVAC/AE** - between MTFs within the Joint Operational Area.
- c. **Strategic MEDEVAC/AE** - from the JOA, to the home nation or other country/safe area.

While NATO doctrine states the priorities and dependency of patients requiring evacuation ²⁷ (see above) it provides no guidance as to the levels of medical capability required; the focus is on the transport assets and the process to control them. Where specific skills are mentioned, guidance remains broad. AJP 4-10(A) ⁸ merely states the range of potential capabilities when discussing pre-hospital ground evacuation transportation:

“There is variation in terms of capabilities and patient capacity. Most will be equipped for basic life support only, but at the top of the scale are advanced support units, staffed with emergency care medical specialists and/or trained specialist paramedic personnel who can provide extended resuscitative care, administer drugs, and begin administration of intravenous fluids in addition to providing basic first aid”.

It takes a similar line with Tactical AE of pre- and post-operative patients, recognizing only the requirement for specialist clinical staff and equipment. AJMedP-2 ²⁸ in its discussion on Incident Response Teams (IRT) suggests that medical capability could range from paramedical staff to primary health care professionals with advanced resuscitation training, to specialist secondary care teams.

US Joint Doctrine ²⁵ focuses on transport assets, priorities and process although in the Appendices of both publications reference is made to CCATT requiring specialty or critical care capability. US Army doctrine ^{29,30} focuses on the priorities for evacuation and not medical capabilities. UK Joint Doctrine does not contain a specific section of medical transfer/evacuation ¹³ and like the Allied and US doctrine it focuses on Priorities and responsibilities rather than capabilities. Guidance in the later UK Joint

doctrine³¹ refers only to appropriately trained medical staff except when describing the Medical Emergency Response Team (MERT) capability:

"It is based on para-medics or emergency medicine nurses but may be augmented by medical officers experienced in skills such as advanced airway management, rapid sequence induction and the maintenance of anesthesia".

UK Army doctrine also acknowledges that the MERT requires crew augmentation for pre hospital emergency care interventions but does not specify further.

Medical Treatment Facilities (MTF)

NATO MTF Role Terminology should provide a common language that enables planners to determine the theatre laydown and facilitates interoperability. In practice, however, National caveats and mission specific nuances have blurred the boundaries over the last 10-15 years.

AJP4-10(A) categorizes MTFs into 4 tiers or Roles(R) on a progressive basis (**Table 3**)³²⁻³⁵. Each Role of care is defined by a minimum clinical capability and not by its capacity or maneuverability. In principle, each MTF contains the minimum capabilities of the Roles below it, while an MTF cannot be reduced below the minimum capabilities of its given numeric descriptor. **UK Joint Doctrine** initially³¹ used NATO terminology, but in the later publication³¹, more caveats are introduced. **UK Army Doctrine**¹⁵ uses NATO terminology without exemptions but does note that boundaries can be blurred. The earlier versions of **US Joint Doctrine**³⁶ did not use the term Roles, instead describing healthcare capabilities from prevention through to definitive care, and only referred to the NATO definitions in a later chapter³⁶. This changed in Jul 12²⁵ when the NATO definitions were included in the main text. **US Army Doctrine**²⁹ initially uses the term 'Levels' rather than Roles but, in broad terms, they describe the same medial capability. This changed in the later doctrine^{22,30} with Roles replacing Levels in line with the NATO terminology. Its R2 description remained consistent throughout, stating that they have the capability to provide packed red blood cells (liquid), limited x-ray, and clinical laboratory support but not surgery. A note emphasizing this appears in the Oct 11 publication highlighting the differences with the Allied publications (See below). There are minimal differences in the definitions of Role 1 and Role 3 MTFs used in Allied^{8,15}, UK^{13,15,31} and US^{29,30,36} doctrine; Joint or single Service. The significant differences are in the descriptions of what constitutes a R2 capability.

Role 2

NATO defines R2 as^{37,38}:

providing an intermediate capability for the reception and triage of casualties, as well as being able to perform resuscitation and treatment of shock to a higher level than Role 1. It will routinely include DCS and may include a limited holding facility for the short term holding of casualties until they can be returned to duty or evacuated. It may be enhanced to provide basic secondary care including primary surgery, intensive treatment unit and nursed beds.

NATO doctrine³⁸ also introduced a delineation in R2 capabilities; those able to support maneuver (R2(LM)) and the more clinically capable variant (R2(E)). The R2(LM) MTFs are described³⁸ as able to conduct triage and advanced resuscitation procedures up to DCS. They will usually evacuate post-surgical cases to Role 3 (or R2E). In addition to Role 1 capabilities, R2(LM) will include:

- a. Specialist medical officer led resuscitation with the elements required to support it.
- b. Routinely DCS with post-operative care.
- c. Field Laboratory capability.
- d. Basic imaging capability.
- e. Reception, regulation and evacuation of patients.
- f. Limited holding capacity.

The same doctrine ³⁹ describes R2 (E) MTFs as:

small field hospital providing basic secondary health care, built around primary surgery, ICU and nursed beds. It is able to stabilize post-surgical cases for evacuation to Role 4 without needing to put them through a Role 3 MTF first.

In addition to R2LM, R2E will include:

- a. Primary (definitive) surgery.
- b. Surgical and medical intensive care capability.
- c. Nursed beds.
- d. Enhanced field laboratory including blood provision.

Initially, **UK Joint Doctrine** ¹³ did not recognize the NATO sub-division but merely stated that R2 MTFs “may, in certain circumstances, include DCS when it will be known as R2+”. This is rectified in a later publication ³¹ describing R2 (LM) as providing “advanced resuscitation up to DCS” and R2 (E) MTFs able to provide Primary surgery and evacuate directly to R4. The later doctrine also includes blood availability but only at R2(E) MTFs. UK Army doctrine ¹⁵ from Mar 12 is coherent with the joint doctrine in its definitions of both R2 (LM) and R2 (E).

US Joint Doctrine initially ³⁶ acknowledged Allied terms only adopting them in the Jul 12 ²⁵ publication. **US Army Doctrine** however, retained its definition and added a note to this effect in Oct 11 ⁴⁰:

Note. The R2 definition used by NATO forces (Allied Joint Publication-4.10[A]) includes [the following] terms and descriptions not used by US Army. US Army doctrine subscribe to the basic definition of a R2 MTF providing greater resuscitative capability than is available at Role 1. It does not subscribe to the interpretation that a surgical capability is mandatory at this Role per the NATO doctrine. The NATO descriptions are—

- *A medical company with a collocated forward surgical team may be referred to as a light maneuver R2 facility.*
- *An enhanced R2 MTF may be used in stability operations scenarios and consists of the medical company, forward surgical team, and other specialty augmentation as deemed appropriate by the situation.*

It should be noted that one of the key capabilities of Forward Resuscitative Surgical Teams is its ability to function effectively when independent of a Role 2 MTF. US Army Forward Surgical Teams, US Air Force Mobile Field Surgical Teams and US Navy Forward Resuscitative Surgical Squadrons are all able to integrate with traditional Role 2 MTFs but are also designed to rely on evacuation assets to rapidly clear stabilized patients, sometimes immediately after surgical procedures are completed. One damage

control surgical capability, the US Air Force Tactical Critical Care Evacuation Team – Enhanced, took the next logical step of integrating forward resuscitative surgical care directly into the evacuation platform – allowing evacuation and surgical stabilization to occur in concert. During the Afghanistan conflict, tactical evacuation capabilities routinely served this role and compensated for the increased patient acuity by providing advanced clinical providers (EMT-Paramedics, Critical Care Nurses, and Emergency Medicine Physicians) when needed.

DISCUSSION

How have operations in Afghanistan impacted on medical doctrine? For the most part this paper has focused on the higher levels of doctrine which we noted change only as a result of measured consideration, usually a top-down process. The one significant example of change at this level (US time to care, the “Golden Hour Initiative”) ^{18,19} only occurred after direction from the Executive authority (highest National Authorities), but even this failed to make it into the joint doctrine until 2012. Otherwise it can be argued that higher level doctrine did not change during the period to reflect reality on the ground; a reality that saw the medical approach to trauma develop significantly. The changes that did occur were captured in the lower tactical levels as standard operating procedures (SOP) and TTP (tactics, techniques and procedures) which were able to react to these changes through bottom up demand. In his thesis “A Revolutionary Approach to Improving Combat Casualty Care”, Hodgetts makes the case that over this period we have seen a revolution in military medical affairs. A summary of the doctrinal changes Hodgetts states in his thesis is at **Table 4**:

These changes are prescriptive and are more about “what” to do rather than “how” to think. That said, the effect these changes have had on the outcomes for trauma casualties on the Battlefield cannot be disputed. The lessons from this campaign will influence higher level doctrine but before changes can be incorporated it is necessary to be clear about what is enduring and applicable universally rather than adaptations specific to that theatre of operations or campaign. The question now is how should our experiences in Afghanistan shape our higher level doctrine for the future?

A distinguishing feature of the Afghanistan conflict was the institution of a trauma system to support continuous near real time system-wide performance assessment and improvement in a theater of war. This continuously learning system energized and accelerated data driven improvements in outcomes through the identification of best practices in prevention and combat casualty care guidelines. Among wounded service members, although injury severity increased, combat mortality steadily decreased. As such a trauma system provides the peripheral and cortical infrastructure for combat casualty care awareness and a methodology for “how to think.” Drag in this system-based cycle of continuous performance assessment and improvement was primarily related to the fragmentation of data capture and compartmentalization of data integration within the Combined-Joint community of practice. Among the many doctrinal latencies associated with the Afghanistan conflict, failure to establish a requirement for an integrated trauma system capable of continuous and concurrent conversion of Combined-Joint data into actionable information to support Combined-Joint operations may be the most recalcitrant and pernicious.

Some change has already occurred; the latest edition of the Allied Joint Doctrine for Medical Support (AJP 4-10(B)) now includes the 10-1-2 guidelines and the level of care to be reached within each time frame⁴¹ as well as the concept of DCR. Yet, despite a stated willingness to adopt Allied doctrine there are still many national caveats regarding what constitutes a R2 MTF and the time lines to a particular Level of Care. R2 MTFs can, under current guidance, be anything from a higher capability than a R1 MTF to a small hospital. This span is probably too great and hinders both planners and interoperability among allies when different capabilities are mandated (e.g., lack of required surgical capability for US R2 elements). As the R2(E) is accepted as being a “deployed hospital” then perhaps it would be simpler if “R3” identified any “deployed hospital” with a suffix denoting its level of capability (level I, II, III). The Afghan campaign highlighted the non-linear nature of medical support where patients can move from point of injury to surgical care without any intermediate steps. Thus there is no need to categorize deployed hospitals as a R2 simply to show that it is further forward. Ultimately, this would then allow R2 MTFs to focus on the intermediary non-surgical capability on the way to the deployed hospital, and subsequently, allow the use of the term for MTFs without surgery. This is something the US has kept within its doctrine as it envisages such facilities being the norm in any larger scale near-peer conflict.

The UK Joint doctrine has now been archived and replaced by AJP 4-10(B), but still retains a caveat stating the UK uses the 10-1-2+2 timeline⁴¹. US doctrine remains as it was in Oct 14 and they too have recorded reservations in AJP 4-10(B) specifically regarding the timelines and the level of care available⁴¹. The primary difference for the US is that R2 does not have to contain surgical capability, therefore timelines are to an appropriate MTF within an hour and not to surgery. This less demanding position is necessary in the higher doctrine as it needs to be relevant to all future campaigns and not just what happened during the most recent operation. Doctrine must also reflect the realities of a large scale conflict with a near peer opponent.

Conversely, another potential solution would be to disassociate forward surgical capabilities from the entanglements of the Role definitions. The tactical advantage of small surgical teams integrated into a joint trauma system can melt away if encumbered by doctrinal attachment to MTFs designed primarily to support trauma care delivery. These small teams can functionally bring lifesaving capabilities to operational areas that would otherwise be supported at the Role 1 level, fully integrate with Role 2 MTFs and augment Role 3 advance surgical capabilities to increase surgical throughput. If forward surgical care doctrine is to be most effective in future operational environment against near peer adversaries, it must recognize the tactical advantage of small size and unencumbered mobility of forward surgical capabilities operating independent of MTFs and reliant on tactical evacuation for relief of limited holding bed capability. This concept is consistent with most existing NATO and other doctrine that focuses on time to appropriate surgical intervention/DCR as opposed to defined Role of care.

While trauma dominates the headlines, the requirement to support disease/non-battle injury (DNBI) cannot be overlooked if R2 MTFs are to be optimized. Commanders can only fight the fit component of a force and, while they have compassion for the injured, this will be their primary focus for large parts of any campaign. Traditionally around 75% of health service support demand is DNBI in nature. We need to apply the same intellectual rigor to collecting and analyzing this data as we have for trauma casualties. A start will be to review combat theater trauma registry data to evaluate treatment at DHC nodes which perhaps could be more conveniently located in a R2 MTF. Data on R1 pre-hospital medical treatment demand will also help shape what extra support could be provided at the R2 MTFs.

One of the significant changes seen in Afghanistan was the increase in the range and the medical capabilities carried on patient movement assets. Typically there were three levels of capability available to the Patient Evacuation Coordination Cell (PECC) to task described in **Table 5**.

There may be an advantage in having levels of MEDEVAC assets in the same way we have levels of MTFs, each with an agreed level of medical capability (probably not far off those above). In the same way MTF capabilities assists planners in configuring the theatre laydown, so will agreed MEDEVAC capabilities. It will equally help develop the mutual understanding required if the higher levels of interoperability are to be achieved. This will then drive changes that support the intelligent tasking of the various MEDEVAC capabilities; a requirement for quicker more timely medical information and the availability of a Medical Common Operating Picture (Med COP).

Limitations in this review include the limited scope of the analysis from 2008 to 2014; future evaluation will focus on allied doctrine from 2014 and beyond. The primary goal of this review was trauma-related combat casualty care, yet primary care and disease non-battle injury comprises much of deployed medical care and is the driving force behind much of the current R2 doctrine. These doctrinal differences were not addressed in this paper.

CONCLUSION

Several discrepancies in medical doctrine persist amongst allied forces. Timelines to definitive care vary among nations. We as allied nations should have clear taxonomy that clearly defines MTF capabilities within the combat casualty care system. The R2 surgical capability discrepancy between US and NATO doctrine should be reconciled. Medical evacuation capabilities on the battlefield would be improved with a taxonomy that reflected the level of capability. Such changes may improve interoperability in a dynamic military landscape.

References

1. The Committee for Tactical Combat Casualty Care (CoTCCC). Tactical combat casualty care guidelines for medical personnel. *Journal of Special Operations Medicine* . 2015;15(3).
2. Drew DM, Snow DM. *Making strategy: an introduction to national security processes and problems*. 1988.
3. NATO Standardization Agency. AAP-06: NATO glossary of terms and definitions. North Atlantic Treaty Organization; 2013.
4. Ministry of Defence. JDP 0-01: UK defence doctrine. British government department ; 2014:32 para 32.17.
5. Ministry of Defence. Army doctrine publication operations. British Army; 2010:2-7 to 2-8.
6. Ministry of Defence. Army doctrine publication operations. British Army; 2010:2-5.
7. Kotwal R, Howard J, Orman J, et al. The effect of a golden hour policy on the morbidity and mortality of combat casualties. *JAMA Surgery*,. 2016;151:1-100.
8. NATO Standardization Agency. AJP 4-10 (A): Allied joint medical support doctrine. North Atlantic Treaty Organization; 2011:3-5 Ch 3 Sect 2 para 3020.
9. NATO Standardization Agency (NSA). AJMedP-1: Allied joint medical planning doctrine. North Atlantic Treaty Organisation; 2009:3-6 para 3031.

10. NATO Standardization Agency. AJMedP-2: Allied joint doctrine for medical evacuation. North atlantic treaty organisation; 2011:1-10.
11. North Atlantic Treaty Organization. STANAG 2087: Medical employment of air transport in the forward area. North Atlantic Treaty Organization; 2008:2 para 8 (a).
12. Ministry of Defence. JWP 4-03: Joint medical doctrine. United Kingdom Government; 2000:3-9 Ch 3 para 306 (e).
13. Ministry of Defence. JWP 4-03: Joint medical doctrine. United Kingdom Government; 2001.
14. NATO Standardization Agency. AD 83-1: ACO Directive on Medical Support to Operations. 2 ed: North Atlantic Treaty Organization (NATO) ; 2009.
15. Boreham A. Army Medical Services Core Doctrine. *Journal of the Royal Army Medical Corps*. 2012;158(4):282-283.
16. Joint force commanders. JP 4-02: Health service support. 2006:B16-B17 Appendix B para 17 sub-para (b) sub-sub-para 11-14.
17. Headquarters Department of the Army. FM 4-02.2: Medical evacuation. US Army; 2007:4-2 Table 4-1.
18. Gates RM. Guidance for the Development of the Force (GDF), Fiscal Years 2010-2015. *JAMA Surgery*. 2008.
19. Ray LJ, Gates RM. Duty: Memoirs of a Secretary at War. *Forum-J Appl Res Con*. 2014;12(2):357-370.
20. Medical Department Center and School. FM 4-02.2 (Including Change 1): Medical Evacuation: The Official U.S. Army Field Manual. U S Department of the Army; 2009:4-2 Ch 4 table 4-1.
21. Headquarters Department of the Army. ATP 4-02: Army health system. Department of Defense; 2011:2-5 Ch. 2 Sect III para 2-16.
22. Headquarters Department of the Army. FM 4-02 (ATP 4-02): Army health system. Department of Defense; 2013:8-2 Ch 8 para 8-6.
23. Headquarters Department of the Army. 4-02.2: Medical evacuation. United States Army; 2014.
24. Joint force commanders. JP 4-02: Health service support. US Government; 2012:B11-B12 Appendix B para 15 sub-para (i) sub-sub-para 11-14.
25. Joint force commanders. JP 4-02: Health service support. US Government; 2012.
26. NATO Standardization Agency (NSA). AMedP2: Allied joint doctrine for medical evacuation. North Atlantic Treaty Organization; 2008.
27. NATO Standardization Agency. AJMedP-2: Allied joint doctrine for medical evacuation. North Atlantic Treaty Organization; 2008:1-10 Ch 11 sect 13 para 0112.
28. NATO Standardization Office. AJMedP-2: Allied joint doctrine for medical evacuation. North Atlantic Treaty Organization; 2008:1-4 Ch 1 Sect 1 para 0104.
29. Headquarters Department of the Army. FM 4-02 (FM 8-10): Force health protection in a global environment. US Army; 2003:2-7 Ch. 1-4 para 2-4 (c).
30. Department of the Army. ATP 4-10: Operational contract support tactics, techniques, and procedures. Department of Defense; 2011:Ch 2, Sect 3.
31. Ministry of Defence. JDP 4-03: Joint medical doctrine. 3rd Edition ed: British government department 2011:Ch. 2-3 Part 1-2 Sect 1-IV para 206 (a) sub-para (b) and Annex 202B.
32. Horne B KB. Battlefield/austere environment trauma system. 2014. Accessed April 24, 2014.
33. Silvia K. Medical care in theater. 2014. Accessed April 23, 2014.
34. Defence Health Board. *Combat trauma lessons learned from military operations of 2001-2013*. 2015.
35. Cubano MA, Lenhart MK. *Emergency war surgery*. 4th ed. Fort Sam Houston, Texas: Borden Institute, U.S. Army, Office of the Surgeon General; 2013.
36. Joint force commanders. JP 4-02: Health service support. 2006.

37. NATO Standardization Agency. AMedP-13(A): NATO glossary of medical terms and definitions. North Atlantic Treaty Organization; 2011:2-55.
38. NATO Standardization Agency. AJP-4.10(A): Allied joint medical support doctrine. 2 ed: North atlantic treaty organisation; 2011.
39. NATO Standardization Agency. AJP 4-10(A): Allied joint medical support doctrine. North Atlantic Treaty Organization; 2011:1-11 para 1046-1047.
40. Headquarters Department of the Army. ATTP 4-02: Army health system. Department of Defense 2011:1-14 Ch 11 Sect 13 para 11-51.
41. NATO Standardization Office. AJP-4.10: Allied joint doctrine for medical support. North Atlantic Treaty Organization; 2015:1-6 Edition B Version 1.

Table 1. Levels of Doctrine (ADP, Army Doctrine Publication; AFM, Army Field Manual; AJP, Allied Joint Publication; AMedP, Allied Medical Publication; AMS, Army Medical Services; ANNEX, United States Air Force Doctrine; ATP, Army Technical Publications; BATLS, Battlefield Advanced Trauma Life Support; BDD, British Defence Doctrine; CGO, Clinical Guidelines for Operations; CPG, Clinical Practice Guidelines; FM, Field Manual; JDP, Joint Doctrine Publication; JP, Joint Publication; JTS, Joint Trauma System; JWP, Joint Warfare Publication; MCRP, Marine Corps Reference Publication; MIMMS, Major Incident Medical Management Support; NWP, Navy Warfare Publication; NTTP, Navy Tactics, Techniques, and Procedures)

Level	Doctrine Publication		
	Allied	US	UK
Philosophy		JP-1	BDD
Principles	AJP-01(D) AJP 4-10 (A)	US Army capstone pub JP 4-02 Army FM 4-02 (ATP 4-02)	JDP 01 Campaigning ADP-Ops JWP 4-03/JDP 4-03 AMS Core Doctrine
Practices (Includes Joint and Allied Environmental, functional and Thematic doctrine)	AMedP-1 AMedP-2 AMedP-13(A)	Army FM 4-02.25 ATP 4-02.3 (Army) ATP 4-02.5 ATP 4-02.55 NWP 4-02 (Navy) NTTP 4-02.2 (Navy) MCRP 4-11.1G (USMC) ANNEX 4-02 (USAF)	AFM
Procedures		JTS CPGs	CGOs MIMMS BATLS

Table 2. Evacuation time planning policy (NATO, North Atlantic Treaty Organization; UK, United Kingdom; US, United States)

Organization	Evacuation Time Planning Policy	Time Period
NATO	1-2-4 hrs	(Jan 08 – Oct 14)
UK	1-2-4 hrs	(Jan 08 – Mar 11)
UK	10-1-2	(Mar 11 – Oct 14)
US	2 hr for Urgent cases and 4 hrs for Priority cases	(Jan 08 – Jul 09)
US	1 hr for Urgent cases and 4 hrs for Priority cases	(Jul 09 – Oct 14)

Table 3. Levels (Roles) of trauma injury care. Adapted from: Horne, et al., 2014; Silva 2014; Cubana, et al., 2013. ³²⁻³⁵

Levels (Roles) of Trauma and Injury Care	
Current Levels (Roles) of Care	Function
Role I Battlefield Care to Battalion Aid Station	<p>Initial level of care/immediate lifesaving measures.</p> <p>Emphasis on stabilizing casualty for evacuation to next level of care.</p> <p>Similar to civilian first responders.</p> <p>Also includes:</p> <ul style="list-style-type: none"> Battlefield Care (Self-Aid/Buddy Aid, Combat Lifesaver and Combat Medic). Battalion Aid Station (far forward aid station with at least one physician available).
Role II Forward Surgical Team	<p>Small, highly mobile, austere surgical team.</p> <p>Provides life-and-limb saving surgical care and typically the first level of surgery available.</p> <p>Limited capabilities, some laboratory, X-ray, mental health and dental services may be available.</p>
Role III Combat Surgical Hospital Air Force Theater Hospital	<p>High volume trauma center.</p> <p>Highest level of treatment within the area of military operations.</p> <p>Provides full range of surgical, medical, laboratory, and radiology capability.</p> <p>Care also includes dental, physical therapy, mental health, obstetrics/gynecology, and primary care services.</p>
Role IV OCONUS Example: Landstuhl Regional Medical Center	<p>Definitive medical and surgical care.</p> <p>Outside of area of military operations or combat, but not within CONUS.</p> <p>Stabilization point before evacuation to CONUS.</p>

Role IV CONUS Walter Reed National Military Medical Center, Brook Army Medical Center	Definitive medical and surgical care OCONUS.

Table 4. Significant doctrinal changes during period of Operation Enduring Freedom (c. 2002 to 2014) (ABC, airway, breathing, circulation; “<C>”, catastrophic hemorrhage; MIST, mechanism, injuries, symptoms, treatment; MTF, medical treatment facility)

Significant Doctrinal Changes
ABC to <C>ABC
Tourniquet use
4 Stages of Combat Resuscitation
Rapid Primary Survey
MIST Report
Clinical Guidelines for Operations
Damage Control Resuscitation (DCR)
Hemostatic Resuscitation
Immediate surgical intervention upon MTF arrival

Table 5. Casualty evacuation platforms

Casualty Evacuation Type	Highest level of Medical Provider	“Level” of Medical Capability	Offensive Arms
Lift of opportunity	Combat Life Saver	<1	Y
US Army Air Ambulance (“DUSTOFF”)	Flight Paramedic	1	N
US Army Air Ambulance (Augmented)	Critical Care Registered Nurse and Flight Paramedic	2	N
US Air Force Rescue Squadron (“PEDRO”)	Para-medics	2	Y
US Air Force Tactical Combat Casualty Evacuation Team (TCCET)	Emergency Medicine Physician, Nurse Anesthetist, Emergency or Critical Care Nurse	3	N
US Air Force Tactical Critical Care Evacuation Team - Enhanced (TCCET -E)	Surgeon, Emergency Physician, Nurse Anesthetist, Emergency Nurse, Operating Room Technician	3+ (Surgical capability)	N
MERT (Medical Emergency Response Team, United Kingdom)	2 Physicians, Emergency Nurse, 4 Para-medics	3	Y

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SERVER-BASED

Article : TA500640

Creator : jtigas

Date : Friday September 9th 2016

Time : 02:00:29

Number of Pages (including this page) : 10

Analysis of injury patterns and roles of care in US and Israel militaries during recent conflicts: Two are better than one

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BACKGROUND: As new conflicts emerge and enemies evolve, military medical organizations worldwide must adopt the “lessons learned.” In this study, we describe roles of care (ROCs) deployed and injuries sustained by both US and Israeli militaries during recent conflicts. The purpose of this collaborative work is facilitate exchange of medical data among allied forces in order to advance military medicine and facilitate strategic readiness for future military engagements that may involve less predictable situations of evacuation and care, such as prolonged field care.

METHODS: This retrospective study was conducted for the periods of 2003 to 2014 from data retrieved from the Department of Defense Trauma Registry and the Israel Defense Force (IDF) Trauma Registry. Comparative analyses included ROC capabilities, casualties who died of wounds, as well as mechanism of injury, anatomical wound distribution, and Injury Severity Score of US and IDF casualties during recent conflicts.

RESULTS: Although concept of ROCs was similar among militaries, the IDF supports increased capabilities at point of injury and Role 1 including the presence of physicians, but with limited deployment of other ROCs; conversely, the US maintains fewer capabilities at Role 1 but utilized the entire spectrum of care, including extensive deployment of Roles 2/2+, during recent conflicts. Casualties from US forces (n = 19,005) and IDF (n = 2,637) exhibited significant differences in patterns of injury with higher proportions of casualties who died of wounds in the US forces (4%) compared with the IDF (0.6%).

CONCLUSIONS: As these data suggest deployed ROCs and injury patterns of US and Israeli militaries were both conflict and system specific. We envision that identification of discordant factors and common medical strategies of the two militaries will enable strategic readiness for future conflicts as well as foster further collaboration among allied forces with the overarching universal goal of eliminating preventable death on the battlefield. (*J Trauma Acute Care Surg.* 2016;00: 00–00. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)

KEY WORDS: Combat casualty care; Israel Defense Forces; prolonged field care; roles of care; trauma; US Army.

Military medicine worldwide shares a universal objective: to advance combat casualty care (CCC) across the continuum of care and save lives.^{1–3} Most systems of care are composed of levels of care with increasing capabilities with the overall objective of triaging, stabilizing, evacuating, and returning the soldier to duty as efficiently as possible. It begins at point of injury (POI)

and continues through escalating roles of care (ROCs, formerly known as echelons), as each elevated role provides increased capabilities in terms of personnel, resources, and competencies.

Recent conflicts have provided the impetus to advance CCC in theater, evident by the reduction in the overall case fatality rate from previous wars.^{4,5} These medical care improvements are the product of “lessons learned” using systematic examination of evidence-based casualty data acquired throughout the continuum of care.⁶ However, although military medicine shares the collective objective of advancing CCC, no work to date has compared ROCs and injury patterns among different militaries for optimal medical management of casualties during combat. Examining different systems of care is now more relevant than ever as the future of CCC may require reappraisal and shift from the standard ROCs to less predictable situations of care and evacuation, such as prolonged field care.⁷

In addition, evaluation of medical experiences gained during recent conflicts and subsequent translation to civilian medicine are extremely timely as emergent data show that the leading cause of death to Americans (<46 years old) is trauma.⁸ Accordingly, civilian medicine can benefit from a decade of military research to advance care, especially in cases of preventable trauma-related deaths.^{9–14} As eloquently stated by the Committee on Military Trauma Care’s Learning Health System and Its Translation to the Civilian Sector, “Improving trauma care will require unprecedented partnership across military and civilian

Submitted: April 29, 2016, Revised: July 14, 2016, Accepted: July 14, 2016, Published online: September 6, 2016.

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This work was presented at the 2015 Military Health System Research Symposium. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the Department of Defense, the US Government, the Israel Ministry of Defense, or Israeli Government. The authors are employees of the US Government or the Israel Government. This work was prepared as part of their official duties, and as such, there is no copyright to be transferred.

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DOI: 10.1097/TA.0000000000001252

J Trauma Acute Care Surg
Volume 00, Number 00

sectors and a sustained commitment from trauma system leaders at all levels.¹⁵

The purpose of this collaborative work is twofold: (1) present ROCs implemented during recent conflicts and postulate whether their deployment affects patient outcome and (2) describe injuries sustained by both US and Israeli militaries in order to expand current knowledge and optimize CCC by supporting wider adaptation of lessons learned in hopes of facilitating strategic readiness for future military engagements.

PATIENTS AND METHODS

A retrospective registry review was performed following institutional regulatory approval with the US Army Institute of Surgical Research US Army Joint Trauma System (JTS) and the Israel Defense Force (IDF) Medical Corps Trauma and Combat Medicine Branch. Data regarding US military were retrieved from the Department of Defense Trauma Registry (DoDTR), which is maintained by the JTS. Data regarding IDF casualties were obtained from the IDF Trauma Registry, which is operated at the Surgeon General's Headquarters, following institutional review board approval of the IDF Medical Corps. The medical data acquisition and collection process of the two militaries were compared.

Roles of Care

In order to compare ROCs between the two military systems, information on the roles of combat care for US forces and IDF was obtained from official guidelines, regulations, and interviews with medical commanders of both armies. Because some variations exist in ROCs between the different US branches (i.e., Army, Air Force, Marines, and Navy), this analysis focused on comparing capabilities between the US Army and the IDF. Special Operations Command medical capabilities for each military were not included in this analysis. Specifically, capability-based ROCs were described and compared in terms of structure, medical staff, lifesaving interventions (LSIs), remote damage control resuscitation, damage control surgery (DCS), imaging capabilities, medical provider type, data collection systems, and evacuation systems of both armies. Evacuation platforms included CASEVAC: tactical evacuation without medical staff; MEDEVAC: tactical evacuation with medical staff; and STRATEVAC: planned, fixed-wing evacuation with medical staff. Lifesaving intervention was defined as a nonsurgical intervention that if not performed immediately would result in loss of life, which includes tourniquet placement (extremity or junctional), intubation, needle thoracocentesis, tube thoracostomy, application of hemostatic dressing, blood product transfusion, and surgical airway protection, as previously described.¹⁶ Remote damage control resuscitation was defined as prehospital administration of blood products, hemostatic medications (e.g., tranexamic acid), and hypotensive resuscitation. Damage control surgery was defined as a surgical intervention that if delayed would result in death or limb loss, which includes, but is not limited to, thoracotomy, fasciotomy, amputation, laparotomy, decompressive craniotomy, or vascular shunt/ligation.

Injury Pattern Analyses

Analyses of battle injuries included all US military (Army, Air Force, Marine Corps, and Navy) injured during Operation

Enduring Freedom, Operation Iraqi Freedom, and Operation New Dawn from 2003 to 2014 and Israeli soldiers (Army, Air Force, Navy) injured mostly during large-scale conflicts (e.g., 2006 Lebanon War and Operation Protective Edge) from 2003 to 2014. Nonbattle injuries, civilian casualties, non-American and non-Israeli soldiers, and those killed in action (KIA) were excluded from this analysis. Comparative analyses of the two cohorts included demographics (gender, age, Injury Severity Score [ISS]), wound distribution, mechanism of injury (MOI), and soldiers died of wounds (DOW), which is defined as death after arrival to a medical treatment facility (MTF), as described elsewhere,⁵ but unlike previous works did not exclude those casualties who were injured in action and returned to duty within 72 hours. It is important to note that the definition of an MTF for the IDF included battalion aid stations with no requirement for surgical capabilities, whereas for the US Army an MTF was defined as Role 2 and above (i.e., sites with surgical capabilities thus not including battalion aid station), as reported in a previous study by Kotwal et al.¹⁷

Regional wound distribution was demarcated based on anatomical body region, as previously described,^{10,11,18} and grouped into the following regions: (1) head and neck (including cervical spine); (2) face (including nose, mouth, eyes, and ears); (3) thorax (including thoracic spine and diaphragm); (4) abdomen and pelvic contents (including abdominal organs and lumbar spine); (5) extremities (including shoulder and pelvic girdle); and (6) external (skin, including burns). For consistency with previous epidemiologic studies,^{10,11,18,19} MOI was grouped into three main categories: (1) explosion (including improvised explosive device, landmine, mortar, shrapnel, bomb, and grenade); (2) gunshot wound (including shrapnel originating from gunshots); and (3) other (including motor vehicle crash, fall and crush, multiple MOIs, and all other battle-associated injuries).

Statistical Analysis

Continuous data were presented as medians and interquartile ranges (IQRs); categorical data were presented as absolute numbers and percentages. Descriptive statistics were performed using *t* test or Wilcoxon-Mann-Whitney test for continuous variables and χ^2 test or Fisher exact test for categorical variable where appropriate. Significance was set at an α (*p*) < 0.05.

RESULTS

Roles of Care

Similar operational principles in systems of care are used by both militaries as each escalating ROC includes the capabilities of the previous level, plus its increased role-specific capabilities. However, when each ROC was examined and compared independently (Table 1), major differences were found in medical capabilities, particularly at POI/Role 1. Importantly, the US military has recently redefined its ROC designation to fit with that of the North Atlantic Treaty Organization, moving from five to four levels of care.²⁰ The main shift was in the definition of Role 4 to include what was previously known as Role 5 hospitals. Therefore, Role 4 is a fixed facility trauma center located in the continental United States (CONUS), and other safe havens.

TABLE 1. Deployed ROCs in US and Israeli Militaries During Recent Conflicts

	Medical Personnel		Capabilities	
	US Army	IDF	US Army	IDF
POI, company level	Combat medic	FMS (physician/paramedic with two medics)	Tourniquet Fluid Analgesia Basic airway (Limited FWB)	Tourniquet Fluid TXA + FDP Analgesia Advanced airway Chest tube
Role 1, battalion level; battalion aid station	PA/NP Combat medics	2 ALS Providers (at least one physician)	Advanced airway FWB	MV Basic monitoring
Role 2, brigade level; FST	Resuscitation company (80) and a surgical team (20)	Resuscitation company (44) and a surgical team (10)	DCR DCS (two OR tables) MT Basic lab Basic radiology	DCR DCS (one OR table) MT Basic lab Basic radiology
Role 3, combat support hospital	Field hospital (245)	Field hospital (150) Deployed in full-scale war or humanitarian missions	Comprehensive surgery CT Scan Lab/BB	Comprehensive surgery CT Scan Lab/BB
Role 4 (OCONUS), fixed facility trauma center	Trauma center outside CONUS	Does not exist	Full spectrum/surgical care	N/A
Role 4 (CONUS), definitive care	Military hospital All specialties	Civilian hospital All specialties	Long term care/rehab	Long term care/rehab

Numbers in parentheses represent number of medical staff/soldiers.

BB, blood bank; CT, computed tomography; DCR, damage control resuscitation; FDP, freeze-dried plasma; FMS, forward medical squad; FWB, fresh whole blood; MV, mechanical ventilation; NP, nurse practitioner; PA, physician assistant; TXA, tranexamic acid; OCONUS, outside the continental United States; OR, operating room; MT, massive transfusion.

Point of Injury/Role 1

Role 1 is POI care, defined as care rendered by a first responder including self-aid, buddy aid, or a combat medic. At the fighting company level, the US Army maintains combat medics with different sets of skills that are able to perform a variety of LSIs, some of which include application of tourniquets, basic airway treatment, and administration of fluids and pain medications, whereas MEDEVAC personnel are trained to perform advanced airway management and chest tubes. Special Operation Command combat medics may be able to perform additional LSI but were not included in this analysis. At the fighting company level, the IDF maintains advanced life savers (ALSs; physician or paramedic)²¹ who are able to provide all treatments given by a medic as well as administer freeze-dried plasma, tranexamic acid, advanced airway management (including intubation), and chest tubes. In addition, units of packed red blood cells are available for use by ALS providers on board helicopters and may be provided by MEDEVAC personnel.

At the battalion level, Role 1 serves as the battalion aid station to triage and initially treat casualties for subsequent evacuation in both forces. The battalion aid station is the forward-most temporary medical facility, typically within the range of enemy attack. The US military rarely has a physician at Role 1, but a licensed independent provider (physician's assistant or nurse practitioner) can provide similar capabilities. The US Army currently supports limited use of a "walking blood bank" concept to support transfusion of fresh whole blood at Role 1.

Some MEDEVAC platforms have the capability to provide packed red blood cells or thawed plasma prior to arrival at the Role 2 forward surgical MTF ("Vampire" missions).^{22,23} Of note, in the recent conflicts in Iraq and Afghanistan, the US Role 1 capability was not routinely utilized for trauma management because of the ability to evacuate casualties rapidly to definitive surgical care at the Role 2 or Role 3 MTFs. At the Role 1 level, the IDF maintains two to five physicians/ALS providers per battalion (two at the BAS and up to three providers are embedded in the companies). In addition to the capabilities offered at the company level, the IDF maintains the ability to apply mechanical ventilation at Role 1, whereas this capability is rare in the US Army. Basic hemodynamic monitoring at Role 1 is available in both militaries.

Role 2/Role 2+

Role 2 capabilities include basic primary care, whereas Role 2+ capabilities include augmented surgical capability, which is typically provided by the Forward Surgical Teams (FST). The US Army defines Role 2 as an MTF with greater resuscitative capability than Role 1, and unlike NATO, DCS is not mandatory at Role 2. Differences in Role 2/2+ capabilities in the IDF and US Army include number of medical personnel in FST (10 vs. 20), operating capabilities (one vs. two operating tables), size of the mobile MTF (500 vs. 1,000 ft²), and the extent of holding capabilities (24 vs. 72 hours), respectively. The concepts of damage control resuscitation and DCS are similar for both

medical systems; however (similar to NATO), definition of Role 2 in the IDF includes DCS, whereas in the US Army DCS is available only at Role 2+. The Role 2 is 100% mobile, and the FST has been deployed extensively by the US forces during recent conflicts. In contrast, because of the proximity of civilian medical facilities, the IDF rarely deploys its Role2/2+, aside from humanitarian missions or full-scale war. In 2013, the IDF deployed a single Role 2+ facility for supporting a humanitarian aid mission to Syrian refugees near the Syrian-Israeli border.^{21,24,25}

Roles III

Role 3 MTF is a combat support hospital capable of providing care to all categories of patients that is designed for holding casualties for a fixed length of time, which is typically up to 72 hours but will vary depending on the theater evacuation policy.²⁶ In both armies, an important exception to the evacuation policy during the more recent conflicts is the prolonged hospitalization of local nationals who could not be evacuated to host nation facilities because of the type or severity of their injuries (e.g., extensive burns). In the IDF, Role 3 has been deployed in times of full-scale war and humanitarian missions.²⁷

Role 4

In the US Army, Role 4 MTFs are defined as hospitals located in CONUS and other designated safe havens (the “communication zone”). During recent conflicts, the US military used Landstuhl Regional Medical Center in Germany as a Role 4 MTF; this fixed facility provided the full spectrum of medical care for US combat casualties until transport to CONUS military hospitals could be facilitated. Role 4 facilities in CONUS were the Walter Reed National Medical Center, the San Antonio Military Medical Center, or the Naval Medical Center San Diego. By comparison, the IDF does not operate military hospitals, but instead relies on the civilian health system, which includes Levels I and II civilian trauma hospitals in Israel’s major cities, because of the proximity of the battlefield to Israel’s borders and to civilian medical facilities.

En Route Care

Of primary importance when contrasting the evacuation systems in the US forces and IDF is the understanding that IDF casualties are primarily mobilized within, or from the vicinity of, Israel’s borders with rapid evacuation times to definitive care civilian trauma centers (Role 4), whereas evacuation of US casualties from POI requires medical support capabilities across multiple platforms (Roles 1–4) and locations. Despite that, the median time from POI to MTF was 70 minutes (IQR, 40–180 minutes) for the US forces and 87 minutes (IQR, 35–120 minutes) for the IDF (Table 2). It is important to note that in this context MTF in the US Army included Roles 2 and 3, whereas in the IDF “time to MTF” reflects evacuation directly to Role 4.

In terms of medical evacuation capabilities, the IDF uses identical medical teams for all ground (one physician and three medics) and aerial (two physicians/physician + paramedic and three medics) platforms, whereas the US military uses various configurations of medical personnel for each evacuation platform across ROCs. Again, the geographic challenges faced by the US forces required escalating capabilities across the continuum of

TABLE 2. Demographics of Combat Casualties in US Forces and IDF

2003–2014	US Forces	IDF	<i>p</i>
No. of patients	19,005	2,637	—
Male, n (%)	18,660 (98.2)	2,563 (97.2)	0.0005
Age, mean (SD)	25.8 (6.1)	22.0 (5.7)	<0.0001
Time from POI to MTF, median (IQR), min	70 (40–180)	87 (35–120)	—
DOW, n (%)	762 (4.0)	15 (0.6)	<0.0001

χ^2 And Wilcoxon-Mann-Whitney tests were used to compare (number and not percent) differences between US forces and IDF.

—, Statistical test was not performed.

care for global evacuation, as well as the size of the force at hand and the availability of physicians. Generally, a flight paramedic or combat medic is the highest level of provider through Role 2 evacuation; a critical care en-route nurse (registered nurse) may augment MEDEVAC from Role 2 to Role 3. Physicians are not routinely part of evacuation teams until STRATEVAC, where a physician, critical care registered nurse, and medic team transport patients from Role 3 to Role 4. In addition, STRATEVAC was routinely used by US military and rarely used by the IDF.

Medical Data Acquisition Process

The data acquisition process in US military is fragmented and varies at the different ROCs with numerous registries that are typically difficult to query.²⁸ The JTS manages the DoDTR, which includes much of the same type of data as the ITR for the IDF for casualties treated in theater and who arrived at an MTF. Data collection at, or close to, POI (Roles 1–2) was rarely performed in US military during the early years of the conflict, but in 2008, the Role 2 registry was developed. The Role 2 registry is a stand-alone database that is populated by clinical personnel who have not received training to abstract data, which leads to heterogeneity in data entries and missing information.²⁹ Unlike Role 2, the Role 3 data are entered into the registry by trained abstractors deployed into theater, which yield data that are more comprehensive and accurate. Nonetheless, all medical data entered into the JTS registry are validated by JTS personnel using available source documentation. Although rich in data, the JTS does not manage KIA data, as these data are collected and maintained by the Armed Forces Medical Examiner System.

In the IDF, the data sources obtained by the ITR include casualty cards filled by caregivers at POI. The casualty cards collect data that depict the following: vital signs, type of treatment given, type of ALS provider, demographics, MOI, and anatomic distribution of injuries.³⁰ Upon arrival at civilian hospitals, complementary data are obtained by trained IDF medical corps personnel through questioning staff and patients, interviewing evacuation teams, and the deployed ALS provider who treated the patient at POI. In this manner, all casualty data obtained from POI to MTF that is provided by military medical personnel is immediately uploaded to the ITR and is available for retrieval by TCMB personnel. However, because the IDF does not hold dedicated military hospitals, data collected at the civilian hospital are released and uploaded manually to the ITR only after

patient discharge, which typically delays considerably the availability of data.

The discrepancies in data acquisition between the two militaries were best exemplified when we attempted to collect LSI data. In the US military, data on LSI were not available from POI/Role 1 but only from the Role 2 registry, with a large amount of missing data. Conversely, early documentation of data from POI/Role 1 by the IDF facilitated the collection of all LSI data (see Table, Supplemental Digital Content 1, <http://links.lww.com/TA/A819>).

Study Populations

Examination of battle-related injuries for the period of 2003 to 2014 included 19,005 US service members and 2,637 IDF service members (Table 2). Of those US forces and IDF cohorts, casualties were predominantly male (98.2% and 97.2%) with a median (IQR) age of 24 years (IQR, 21–28 years) and 21 years (IQR, 19–22 years). More importantly, there was significantly higher percentage of casualties DOW in the US forces as compared with the IDF ($p < 0.0001$).

Wound Distribution

Injury severity score was similar in the IDF and US military. Evaluation of wound distribution of “all injuries” revealed that in both militaries “external” injuries (e.g., burns, skin lacerations, etc.) were the most frequent followed by injuries to the **T3** extremities and head and neck body regions (Table 3). However, injuries to the head and neck, face, and abdomen and pelvic regions were significantly more abundant in the IDF compared with the US forces ($p < 0.0001$). In contrast, injuries to the extremities were significantly more prevalent among US casualties compared with the IDF ($p = 0.0001$). There was no statistical difference in the average number of wounds per casualty.

Evaluation of critically injured patients (ISS ≥ 25) revealed different distributions of injuries. Specifically, external injuries were less prevalent in the critically injured as compared with “all injuries” in both US military and the IDF; instead, injuries were distributed more evenly among other body regions with a large increase in injuries to the “thorax” and “abdomen and pelvic” regions (Table 3). Importantly, the total wounds per casualty also increased dramatically (from 2.3 to 3.6 and from 2.2 to 3.5 in the US forces and the IDF, respectively), which logically follows as those that were critically injured had sustained more injuries overall.

Mechanism of Injury

In both cohorts, the majority of casualties sustained injuries because of explosion followed by gunshot wounds (Table 4). **T4** However, significant differences were found between the two cohorts as explosion accounted for 76.8% of injuries in the US forces compared with 40% of injuries in the IDF ($p < 0.0001$). Conversely, significantly more gunshot wounds accounted for injuries in the IDF (28.7%) compared with injuries in US military (18.5%) ($p < 0.0001$). Prevalent injuries in “other” MOI included motor vehicle collision, blunt trauma, or two or more MOIs, which were significantly more frequent in the IDF (31.3%), as compared with those of US military (4.7%) ($p < 0.0001$). Evaluation of critically injured patients did not change the distribution of MOIs.

DISCUSSION

Combat casualty care is markedly different from prehospital care that is rendered in the civilian sector. The tactical environment with its austere conditions should be taken into consideration when providing care on the battlefield.^{1,31} The fact that injury pattern is dependent on the type of warfare, the deployed ROCs, the MOI, and the efficiency of the protective gear used, as well as the difficulty in the collection of casualty medical data considerably, limits our ability to advance CCC across the continuum of care.³² Nevertheless, as new conflicts emerge, military medical organizations must evolve and adapt in order to face the ever-changing battlefield. This joint effort is the first to compare large-scale data among different military forces engaged in diverse types of asymmetric warfare.

In this study, comparison of ROCs implemented during recent US and Israeli conflicts revealed significant differences in capabilities and medical personnel. In 2012, the IDF medical corps initiated a 10-year strategic buildup plan coined as “My Brother’s Keeper.”³³ Inspired by the low case fatality rate reported by NATO, in this plan, the IDF set a goal of eliminating preventable deaths and improving the medical system as a whole.^{33–35} In an attempt to increase survival rates, the IDF supports increased capabilities at POI compared with the US military because of the fact that the majority of deaths occur at (or close to) POI. Although no definitive conclusions can be made, the presence of a physician with advanced medical capabilities (advanced

TABLE 3. Distribution of Wounds by Anatomical Region in US Forces and IDF Casualties

	All Injuries			ISS ≥ 25		
	US Forces, n = 19,005	IDF, n = 2,637	p	US Forces, n = 1,960 (10.3%)	IDF, n = 208 (7.9%)	p
ISS, mean (SD)	10.1 (11.1)	10.5 (10.4)	0.13	35.6 (12.2)	36.0 (12.6)	0.66
Head and neck, n (%)	8,103 (18.7)	953 (16.2)	<0.0001	1,255 (17.8)	127 (17.4)	0.83
Face, n (%)	4,708 (10.9)	471 (8.0)	<0.0001	842 (11.9)	82 (11.3)	0.60
Thorax, n (%)	2,792 (6.4)	416 (7.1)	0.06	1,041 (14.7)	112 (15.4)	0.64
Abdomen and pelvic, n (%)	3,536 (8.2)	293 (5.0)	0.0001	1,061 (15.0)	112 (15.3)	0.79
Extremities, n (%)	9,098 (21.0)	1,632 (27.8)	0.0001	1,226 (17.4)	123 (16.9)	0.76
External, n (%)	15,093 (34.8)	2,103 (35.8)	0.71	1,641 (23.2)	172 (23.6)	0.81
Total wounds (per casualty)	43,330 (2.3)	5,868 (2.2)	—	7,066 (3.6)	728 (3.5)	—

χ^2 Test was used to compare anatomical wound distribution between US forces and IDF. Percent wound distribution was calculated based on the total of injuries per body region to the total number of wounds. Casualties KIA were excluded from this analysis.

TABLE 4. Mechanism of Injury in US Forces and IDF

	MOI, All		<i>p</i>	MOI, ISS ≥ 25		<i>p</i>
	US Forces, n = 19,005	IDF, n = 2,637		US Forces, n = 1,960 (10.3%)	IDF, n = 208 (7.9%)	
Explosion, n (%)	14,592 (76.8)	1,054 (40)	<0.0001	1,490 (76.0)	78 (37.5)	0.0001
Gunshot wound, n (%)	3,512 (18.5)	758 (28.7)	<0.0001	413 (18.5)	62 (29.8)	0.005
Other, n (%)	901 (4.7)	825 (31.3)	<0.0001	57 (2.9)	68 (32.7)	0.0001

χ^2 Test was used to compare MOI between US forces and IDF for both MOIs. Casualties KIA were excluded from this analysis.

airway, chest tube, TXA, and FDP) in the IDF may potentially translate to improved short and long-term patient outcomes.³⁶ Due to missing data in both the US far forward roles of care as well patient outcome in the IDF cohort, this hypothesis is not presented here but should be further tested by evaluating patient outcome among the two military systems.

A comparison of evacuation time between militaries revealed a longer median time to MTF in the IDF (87 minutes) compared with the US military (70 minutes). Although this may seem contradictory at first because of Israel's short evacuation distances, a plausible explanation lies with the differences in MTFs; specifically, in the US military, "time to MTF" was primarily derived from POI to Roles 2 and 3. In contrast, in the IDF, the majority of casualties were evacuated to Role 4 facilities, because of the proximity of battlefield to civilian centers. Although a comparison of time to treatment by an ALS provider was not performed (not available in the DoDTR), it is most likely shorter for the IDF, where physicians and paramedics are deployed to the frontlines.

Prehospital data collection for the establishment of a prehospital registry has been the goal of military organizations in recent years, but remains a challenge.^{37–39} Data collection, analysis, and evidence-based adjustments to clinical practice guidelines are fundamental steps in reaching this goal.⁴⁰ By comparing the two data collection systems, we have uncovered important strengths and weaknesses of each military system. Specifically, while the IDF focuses on POI/Role 1 data collection, the US military has only fragmented data of early point of care with the recent development and adaptation of the Role 2 registry (see Table, Supplemental Digital Content 1, <http://links.lww.com/TA/A819>). However, because of the dedicated military MTF in the US military, Roles 3 and 4 casualty data (including rehabilitation data) are an integral part of the trauma registry, whereas in the IDF, data acquired at civilian hospitals are uploaded manually to the ITR after a considerable delay (following patient's discharge).

Data acquisition and analysis followed by implementation of lessons learned while performing constant reappraisal constitute a fundamental working concept, which allows for timely, ongoing improvements that can be achieved by necessary adaptation of the CCC system. Gathering high-quality data from POI to rehabilitation and constructing a dedicated trauma registry serve as the basis for these fundamental improvement processes. It is our opinion that acquisition of data is the first and perhaps the most important aspect of translating evidence-based medicine to lives saved in both military and civilian sectors.

A comparison of injury severity revealed similar ISS in US military and the IDF. Interestingly, significantly fewer

soldiers DOW in the IDF compared with the US military ($p < 0.0001$), a fact that may be also attributed to adequate treatment early after injury (at POI), or because of the different MOIs (e.g., greater proportion of gunshot wounds in IDF). Another factor that may explain why fewer casualties DOW lies with its definition; namely, DOW are soldiers who died after arriving to an MTF. Yet, although, by definition, an MTF in the IDF system includes Role 1, IDF casualties primarily arrive at definitive care hospitals (Role 4), which offer the entire spectrum of care. Therefore, whereas DOW in US forces provides a measure of field triage and care rendered at Roles 2 to 3,¹⁸ DOW in the IDF more closely represents deaths treated at Role 4 that were most likely not potentially preventable.³⁶ Perhaps the fact that the IDF maintains ALS providers at the frontlines may also contribute to the lower DOW in the IDF compared with the US military. For example, the presence of ALS providers at POI/Role 1 in the IDF allows for an early declaration of death, which increases the KIA rates while reducing the proportion of casualties who DOW, as well as minimizes the risk for unnecessary evacuation. It is important to note, however, that the speculative opinions made by the authors regarding DOW rates necessitate appropriate methodological analysis for drawing a firm conclusion. For example, early advanced treatment at POI may potentially lower the rate of KIA by delaying the death of the more severely injured, which could translate into higher DOW rates.

Analysis of injuries by body region showed similar wound distribution in both militaries as external injuries were the most frequent, followed by extremities, head and neck, and face (Table 2). While the number of wounds per patients was similar among militaries, significant differences were found in all injured body regions ($p < 0.0001$) except for thoracic ($p = 0.06$) and external injuries. Interestingly, the IDF injury signature is somewhat similar to injuries sustained in low-intensity conflicts of previous years during the second Palestinian uprising as reported by Lakstein et al.,⁴¹ where the predominant injured body regions were the head, face, and neck (54.2%) followed by the limbs (50.0%). This fact, along with the similar distribution of wounds in both armies, may suggest that current armor system may warrant further scrutiny and improvement.^{10,35,42} This supposition is further supported by the fact that the proportion of injuries to the "thorax" and "abdomen and pelvic" body regions dramatically increased in patients who were critically injured (Table 3). For this purpose, as part of the "My Brother's Keeper" plan, the IDF is focusing on the development of more efficient personal body armor with special attention to junctional body regions (i.e., neck, armpit, groin), as well as a durable, lightweight, bulletproof helmet,³³ as lethal brain injuries are regarded as nonpreventable deaths.⁴³

Analysis of MOI revealed that in both cohorts the majority of casualties sustained injuries due to explosion followed by gunshot wounds (Table 4). However, a significantly higher proportion of injuries were sustained because of explosion in the US cohort compared with the IDF (76.8% vs. 40%, respectively, $p < 0.0001$). Conversely, significantly higher proportion of gunshot wounds accounted for injuries in the IDF compared with injuries in US military (28.7% vs. 18.5%, respectively, $p < 0.0001$). Finally, injuries classified as “other” (which include motor vehicle crash, fall and crash, multiple MOIs, smoke inhalation, and other battle-associated injuries) were significantly more frequent in the IDF compared with US military (31.3% vs. 4.7%, respectively, $p < 0.0001$). One factor that may contribute to the higher rates of injuries classified as “other” is the need of IDF soldiers to pacify violent disturbances. This varying MOI distribution between the two militaries points to a different type of warfare, which requires further evaluation that may contribute to future mission planning. For example, it is the authors’ opinion that higher rates of gunshot wounds in IDF are due to the limited mission episodes in Israel, such as the Second Lebanon War (2006), Operation Cast Lead (2008–2009), and Operation Protective Edge (2014) lasting 34, 22, and 50 days, respectively. These recent conflicts were characterized by massive field maneuvers leading to close encounters with enemy forces and higher a proportion of gunshot wounds.

Our study has some important limitations. The first limitation concerns the retrospective nature of the study. The second limitation concerns the challenge of data collection from the battlefield during combat situations that leads to missing data, especially for US military data acquired at Role 2. Documentation at POI/Role 1 is limited in the US military but is much more comprehensive in the IDF.²⁴ Another challenge is the different definition of an MTF; in the IDF, Role 1 constitutes an MTF, whereas in the US military, the previous definition of an MTF described by Holcomb et al.,⁵ which included Role 1, was recently updated by Kotwal et al.¹⁷ to include surgical capabilities, which are offered only at Roles 2+. Moreover, the extended period of this study (2003–2014) introduces various unknown confounders that limit this comparative analysis. For example, standard definitions, ROC designations and capabilities, weaponry, tactics, armor systems, and the diverse theaters of operations have evolved dramatically throughout this study period. Another limitation exists with the analysis of data using ISS, which provides only an abstract of the dataset (three most severely injured body regions) and does not portray the entire injury pattern. In addition, because of the fact that DoDTR does not contain KIA data, the injury mechanism is missing for casualties who were KIA. Finally, because of inherent problems with the registries as outlined previously, our %DOW analysis differs in its standard definition from previous reports in that it does not exclude casualties who returned to duty from casualties who were wounded in action (WIA); that is, in our analysis, $\%DOW = \frac{DOW}{WIA} \times 100\%$, where WIA includes casualties who returned to duty within 72 hours; for fair comparison, however, the same analysis was performed for both militaries.

CONCLUSIONS

As these data suggest, combat is dynamic, and injury patterns are both conflict and system specific, evident by the

significant differences in MOI and wound distribution among the two forces. Therefore, identifying discordant factors between the two forces and fostering collaboration with other militaries enable strategic preparation for future conflicts with the overarching goal of eliminating preventable death on the battlefield. Future collaborative studies should be carried out to examine casualty outcomes of the two systems, as well as different trauma systems to allow for iterative learning.

AUTHORSHIP

B.A. and A.B. equally contributed to the study design, data collection, analysis and interpretation, writing, and critical revisions. E.A.M.-S. and T.D.L. contributed to the study design, US data collection, analysis and interpretation, writing, and critical revisions. L.C.C., J.C.W., H.P., and K.R.G. provided data interpretation and critical revisions. E.G. contributed to the study design, data analysis and interpretation, writing, and critical revisions.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

- Butler FK Jr, Blackburne LH. Battlefield trauma care then and now: a decade of tactical combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6 Suppl 5):S395–S402.
- Blackbourne LH, Baer DG, Eastridge BJ, Kheirabadi B, Bagley S, Kragh JF, Cap AP, Dubick MA, Morrison JJ, Midwinter MJ, et al. Military medical revolution: prehospital combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6 Suppl 5):S372–S377.
- Glassberg E, Nadler R, Erlich T, Klien Y, Kreiss Y, Kluger Y. A decade of advances in military trauma care. *Scand J Surg*. 2014;103(2):126–131.
- Rasmussen TE, Gross KR, Baer DG. Where do we go from here? Preface. US Military Health System Research Symposium, August 2013. *J Trauma Acute Care Surg*. 2013;75(2 Suppl 2):S105–S106.
- Holcomb JB, Stansbury LG, Champion HR, Wade C, Bellamy RF. Understanding combat casualty care statistics. *J Trauma*. 2006;60(2):397–401.
- Eastridge BJ, Hardin M, Cantrell J, Oetjen-Gerdes L, Zubko T, Mallak C, Wade CE, Simmons J, Mace J, Mabry R, et al. Died of wounds on the battlefield: causation and implications for improving combat casualty care. *J Trauma*. 2011;71(1 Suppl):S4–S8.
- Rasmussen TE, Baer DG, Cap AP, Lein BC. Ahead of the curve: sustained innovation for future combat casualty care. *J Trauma Acute Care Surg*. 2015;79(4 Suppl 2):S61–S64.
- Rhee P, Joseph B, Pandit V, Aziz H, Vercruysse G, Kulvatunyou N, Friesse RS. Increasing trauma deaths in the United States. *Ann Surg*. 2014;260(1):13–21.
- Rasmussen TE, Baer DG, Goolsby C. The giving back: battlefield lesson to national preparedness. *J Trauma Acute Care Surg*. 2016;80(1):166–167.
- Owens BD, Kragh JF Jr, Wenke JC, Macaitis J, Wade CE, Holcomb JB. Combat wounds in Operation Iraqi Freedom and Operation Enduring Freedom. *J Trauma*. 2008;64(2):295–299.
- Belmont PJ Jr, McCrisky BJ, Sieg RN, Burks R, Schoenfeld AJ. Combat wounds in Iraq and Afghanistan from 2005 to 2009. *J Trauma Acute Care Surg*. 2012;73(1):3–12.
- Owens BD, Kragh JF Jr, Macaitis J, Svoboda SJ, Wenke JC. Characterization of extremity wounds in Operation Iraqi Freedom and Operation Enduring Freedom. *J Orthop Trauma*. 2007;21(4):254–257.
- Belmont PJ, Schoenfeld AJ, Goodman G. Epidemiology of combat wounds in Operation Iraqi Freedom and Operation Enduring Freedom: orthopaedic burden of disease. *J Surg Orthop Adv*. 2010;19(1):2–7.
- Champion HR, Holcomb JB, Lawnick MM, Kellihier T, Spott MA, Galanteau MR, Jenkins DH, West SA, Dye J, Wade CE, et al. Improved characterization of combat injury. *J Trauma*. 2010;68(5):1139–1150.
- Committee on Military Trauma Care’s Learning Health System and Its Translation to the Civilian Sector, Board on Health Sciences Policy, Board on the Health of Select Populations, Health and Medicine Division, The National Academies of Sciences, Engineering, Medicine. *A National*

Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury. National Academy of Sciences. National Academies Press; 2016.

16. Laird JR, Beberta VS, Burns CJ, Laird KF, Rasmussen TE, Renz EM, King BT, Fernandez W, Gerhardt R, Butler F, et al. Prehospital interventions performed in a combat zone: a prospective multicenter study of 1,003 combat wounded. *J Trauma Acute Care Surg*. 2012;73(2 Suppl 1):S38–S42.
17. Kotwal RS, Howard JT, Orman JA, Tarpey BW, Bailey JA, Champion HR, Mabry RL, Holcomb JB, Gross KR. The effect of a golden hour policy on the morbidity and mortality of combat casualties. *JAMA Surg*. 2016;151(1):15–24.
18. Belmont PJ Jr, Goodman GP, Zacchilli M, Posner M, Evans C, Owens BD. Incidence and epidemiology of combat injuries sustained during “the surge” portion of Operation Iraqi Freedom by a U.S. Army brigade combat team. *J Trauma*. 2010;68(1):204–210.
19. Schoenfeld AJ, Dunn JC, Bader JO, Belmont PJ Jr. The nature and extent of war injuries sustained by combat specialty personnel killed and wounded in Afghanistan and Iraq, 2003–2011. *J Trauma Acute Care Surg*. 2013;75(2):287–291.
20. Borden Institute, US Army Medical Department Center and School. *Emergency War Surgery*. 4th ed. Fort Sam Houston, TX: Borden Institute; 2013:17–28.
21. Avi Benov, Elon G, Baruch EN, Avi S, Gilad T, Moran L, Itay Z, Ram S, Tarif B, David D, et al. Augmentation of point of injury care: reducing battlefield mortality—the IDF experience. *Injury*. 2016;47(5):993–1000.
22. Malsby RF 3rd, Quesada J, Powell-Dunford N, Kinoshita R, Kurtz J, Gehlen W, Adams C, Martin D, Shackelford S. Prehospital blood product transfusion by U.S. army MEDEVAC during combat operations in Afghanistan: a process improvement initiative. *Mil Med*. 2013;178(7):785–791.
- AQ6 23. Mavity ME, Col U, MC, CFS, Surgeon C. *Vampire Program: Urgent Resuscitation Using Blood Products during Tactical Evacuation From Point of Injury*. In: Army Dot, editor. 2016.
24. Benov A, Glassberg E, Nadler R, Gendler S, Erlich T, Bader T, Rasmussen TE, Kreiss Y. Role I trauma experience of the Israeli Defense Forces on the Syrian border. *J Trauma Acute Care Surg*. 2014;77(3 Suppl 2):S71–S76.
25. Glassberg E, Badr T, Nadler R, Benov A, Zarka S, Kreiss Y. When humanitarianism trumps politics. *Isr Med Assoc J*. 2015;17(6):339–340.
26. Department of the Army. *Medical Evacuation in a Theater of Operations*. Washington, DC:Department of the Army;2000.
27. Kreiss Y, Merin O, Peleg K, Levy G, Vinker S, Sagi R, Abargel A, Bartal C, Lin G, Bar A, et al. Early disaster response in Haiti: the Israeli field hospital experience. *Ann Intern Med*. 2010;153(1):45–48.
28. Krueger CA, Ching W, Wenke JC. Completing records-based research within the military: a user’s guide. *J Surg Orthop Adv*. 2013;22(1):82–94.
29. Mann-Salinas EA, Le TD, Shackelford SA, Bailey JA, Stockinger ZT, Spott MA, Wirt MD, Rickard R, Lane IB, Hodgetts T, et al. Evaluation of Role 2 (R2) medical resources in the Afghanistan combat theater: initial review of the Joint Trauma System R2 Registry [published online ahead of print April 27, 2016]. *J Trauma Acute Care Surg*. 2016.
30. Benov Avi, Elon G, Baruch EN, Avi S, Gilad T, Moran L, Itay Z, Ram S, Tarif B, David D, et al. Augmentation of point of injury care: reducing battlefield mortality—the IDF experience. *Injury*. 2016;47(5):993–1000.
31. Butler FK Jr, Holcomb JB, Giebner SD, McSwain NE, Bagian J. Tactical combat casualty care 2007: evolving concepts and battlefield experience. *Mil Med*. 2007;172(11 Suppl):1–19.
32. Glassberg E, Lipsky AM, Abramovich A, Dagan D, Kreiss Y. Apples and oranges: looking forward to the next generation of combat casualty care statistics. *J Trauma Acute Care Surg*. 2013;74(2):683–686.
33. Glassberg E, Nadler R, Lipsky AM, Shina A, Dagan D, Kreiss Y. Moving forward with combat casualty care: the IDF-MC strategic force buildup plan “My Brother’s Keeper”. *Isr Med Assoc J*. 2014;16(8):469–474.
34. Kotwal RS, Montgomery HR, Kotwal BM, Champion HR, Butler FK Jr, Mabry RL, Cain JS, Blackburne LH, Mechler KK, Holcomb JB. Eliminating preventable death on the battlefield. *Arch Surg*. 2011;146(12):1350–1358.
35. Schwartz D, Glassberg E, Nadler R, Hirschhorn G, Marom OC, Aharonson-Daniel L. Injury patterns of soldiers in the second Lebanon war. *J Trauma Acute Care Surg*. 2014;76(1):160–166.
36. Barzilai L, Harats M, Wiser I, Weissman O, Domniz N, Glassberg E, Stavrou D, Zilinsky I, Winkler E, Hiak J. Characteristics of improvised explosive device trauma casualties in the Gaza Strip and other combat regions: the Israeli experience. *Wounds*. 2015;27(8):209–214.
37. Perkins JG, Brosch LR, Beekley AC, Warfield KL, Wade CE, Holcomb JB. Research and analytics in combat trauma care: converting data and experience to practical guidelines. *Surg Clin North Am*. 2012;92(4):1041–1054.
38. Smith LE. The deployed electronic medical record. *US Army Med Dep J*. 2008;63–67.
39. Kotwal RS, Butler FK, Montgomery HR, Brunstetter TJ, Diaz GY, Kirkpatrick JW, Summers NL, Shackelford SA, Holcomb JB, Bailey JA. The Tactical Combat Casualty Care casualty card TCCC guidelines? Proposed change 1301. *J Spec Oper Med*. 2013;13(2):82–87.
40. Katzenell U, Lipsky AM, Abramovich A, Huberman D, Sergeev I, Deckel A, Kreiss Y, Glassberg E. Prehospital intubation success rates among Israel Defense Forces providers: epidemiologic analysis and effect on doctrine. *J Trauma Acute Care Surg*. 2013;75(2 Suppl 2):S178–S183.
41. Lakstein D, Blumenfeld A. Israeli Army casualties in the second Palestinian uprising. *Mil Med*. 2005;170(5):427–430.
42. Ari AB. Eye injuries on the battlefields of Iraq and Afghanistan: public health implications. *Optometry*. 2006;77(7):329–339.
43. Eastridge BJ, Mabry RL, Seguin P, Cantrell J, Tops T, Uribe P, Mallett O, Zubko T, Oetjen-Gerdes L, Rasmussen TE, et al. Death on the battlefield (2001–2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6 Suppl 5):S431–S437.

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Evaluation of role 2 (R2) medical resources in the Afghanistan combat theater: Initial review of the joint trauma system R2 registry

AQ1 **Elizabeth A. Mann-Salinas, PhD, RN, Tuan D. Le, MD, DrPH, Stacy A. Shackelford, MD, Jeffrey A. Bailey, MD, Zsolt T. Stockinger, MD, Mary Ann Spott, PhD, Michael D. Wirt, MD, PhD, Rory Rickard, PhD, FRCS, Ian B. Lane, BDS, MPH, Timothy Hodgetts, PhD, FRCP, Sylvain Cardin, PhD, Kyle N. Remick, MD, and Kirby R. Gross, MD, Houston, Texas**

BACKGROUND:	A Role 2 registry (R2R) was developed in 2008 by the US Joint Trauma System (JTS). The purpose of this project was to undertake a preliminary review of the R2R to understand combat trauma epidemiology and related interventions at these facilities to guide training and optimal use of forward surgical capability in the future.
METHODS:	A retrospective review of available JTS R2R records; the registry is a convenience sample entered voluntarily by members of the R2 units. Patients were classified according to basic demographics, affiliation, region where treatment was provided, mechanism of injury, type of injury, time and method of transport from point of injury (POI) to R2 facility, interventions at R2, and survival. Analysis included trauma patients aged ≥18 years or older wounded in year 2008 to 2014, and treated in Afghanistan.
RESULTS:	A total of 15,404 patients wounded and treated in R2 were included in the R2R from February 2008 to September 2014; 12,849 patients met inclusion criteria. The predominant patient affiliations included US Forces, 4,676 (36.4%); Afghan Forces, 4,549 (35.4%); and Afghan civilians, 2,178 (17.0%). Overall, battle injuries predominated (9,792 [76.2%]). Type of injury included penetrating, 7,665 (59.7%); blunt, 4,026 (31.3%); and other, 633 (4.9%). Primary mechanism of injury included explosion, 5,320 (41.4%); gunshot wounds, 3,082 (24.0%); and crash, 1,209 (9.4%). Of 12,849 patients who arrived at R2, 167 (1.3%) were dead; of 12,682 patients who were alive upon arrival, 342 (2.7%) died at R2.
CONCLUSION:	This evaluation of the R2R describes the patient profiles of and common injuries treated in a sample of R2 facilities in Afghanistan. Ongoing and detailed analysis of R2R information may provide evidence-based guidance to military planners and medical leaders to best prepare teams and allocate R2 resources in future operations. Given the limitations of the data set, conclusions must be interpreted in context of other available data and analyses, not in isolation. (<i>J Trauma Acute Care Surg.</i> 2016;00: 00–00. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)
LEVEL OF EVIDENCE:	Descriptive study, level VI.
KEY WORDS:	Combat; trauma; forward surgical care; joint trauma system; role 2.

There has yet to be a comprehensive review of the impact of Role 2 (R2) medical resources in the combat theater. Although R2 registry (R2R) was established by the Joint Trauma System (JTS) in 2008, no systematic evaluation for these data has been reported. Analysis may provide military planners and medical leaders with information to support optimal team training and optimum allocation of R2 resources in future operations.

Combat casualty care occurs across a continuum within the US military evacuation system:

- 1) on-scene care (“point of injury”, Role 1);

- 2) fixed or mobile facilities for immediate surgical stabilization and resuscitation (R2);
- 3) full-spectrum theater trauma care (Role 3 [R3]);
- 4) trauma care provided at fixed facilities outside of the United States (Role 4); and finally,
- 5) definitive care hospitals in the United States.

The North Atlantic Treaty Organization (NATO) defines R2 as a trauma unit with resuscitative capability that will routinely provide damage control surgery.¹

While data are available documenting the operational impact of individual R2 elements,² no systematic and comprehensive evaluation of R2 use has been reported. Such analysis is further complicated by the existence of a variety of R2 elements available to each service, unit, country, and operational requirement. Each US Service has R2 for damage control surgery and resuscitation: US Army Forward Surgical Team, US Marine Corps Forward Resuscitative Surgical System, US Navy Fleet Surgical Teams and Expeditionary Resuscitative Surgical Systems, and US Air Force Surgical Team. Our NATO partners also have this same capability. For example, the United Kingdom (UK) has an R2 surgical team that can support damage control surgery in addition to resuscitative capability. Role 2 s can be independently located on a forward operating base. Role 2 s of any US Service can be collocated with the medical companies of a

Submitted: January 19, 2016, Revised: February 10, 2016, Accepted: February 15, 2016.
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DOI: 10.1097/TA.0000000000001092

J Trauma Acute Care Surg
 Volume 00, Number 00

US Army brigade support battalion, a US Air Force mobile aeromedical staging facility, or a US Navy shock trauma platoon. Definitions of NATO from the Allied Joint Medical Support Doctrine (AJP-4.10A) clarify light maneuver and enhanced R2 elements.¹

An R2 element is a medical capability that augments or enhances other assets by providing lifesaving surgical interventions and damage control resuscitation; however, R2 teams lack the capability for extended postoperative support, generally not intended to hold patients beyond 72 hours.³ For example, most R2 units in Afghanistan were army forward surgical teams; teams were often “split” to support two geographic regions (Fig. 1). The basic US Marine Corps R2 (Forward Resuscitative Surgery System [FRSS]) contains only a single surgical table and less than half the personnel of an Army R2.

Although the Department of Defense Trauma Registry (DoDTR) does contain R2 casualties, initially, inclusion was limited until 2014 to casualties evacuated to and treated at a R3. Until the R2R was established in 2008, it is unknown how much of the medical care provided before R3 admission was fully captured; despite its implementation as a voluntary reporting system, it remains unknown what percentage of R2 workload has actually been captured by the R2R, but presumably, it captures more return-to-duty and R2 deaths than the DoDTR had previously. A number of published reports document the activities and performance of R2 elements during either Operation Enduring Freedom (OEF, 2001 to present) or Operation Iraqi Freedom (OIF, 2003 to 2011) before 2008. During OEF, most reports involved Army forward surgical teams with limited numbers of trauma casualties;^{4–7} one report from a Naval surgical team described

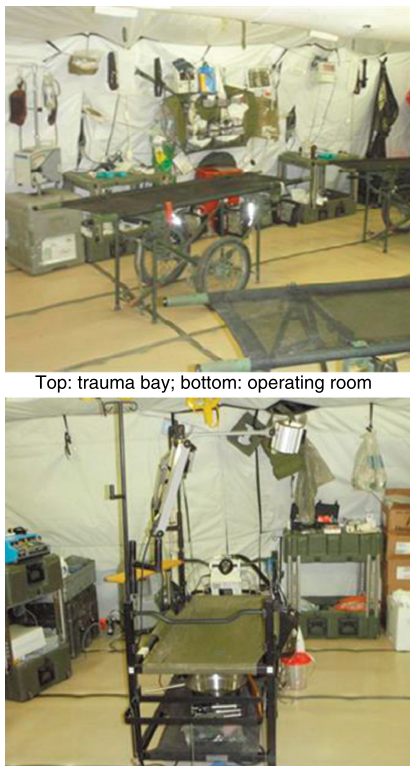
46 combat-related casualties.⁸ The most informative report included 761 patients with detailed patient type, mechanism of injury or disease, location of injury, severity scores, and surgical procedures performed.⁹ Subsequent reports with fewer patients provided information on blood usage and associated outcomes,^{10,11} and various R2 experiences without specific patient data.^{12–18} Operation Iraqi Freedom and Operation New Dawn (OND) reports of R2 experiences were dominated by the experiences of the Navy's forward resuscitative surgical teams^{19–24} with only two Army R2 experiences;^{25,26} the OIF reports were before 2008. In summary, these published reports provide insufficient comprehensive information concerning the patients, injuries, and clinical interventions associated with R2 facilities. The purpose of this project was to describe the initial review of available R2R data as a first step toward understanding R2 use to support future deployment of forward surgical capabilities.

PATIENTS AND METHODS

A retrospective review of the JTS R2R was conducted following institutional regulatory approval.

Role 2 Registry Description

The R2R is a stand-alone Microsoft Access database that has remained unlinked to the larger DoDTR because it has not been fully verified against source patient medical records. This registry contains a convenience sample of patients treated at R2 facilities since 2008 at levels of medical care that previously did not have full trauma registry capabilities (trained and



Top: trauma bay; bottom: operating room

US Army Forward Surgical Team (FST)

72 hour continuous operations

- 2 Operating room (OR) tables; 10 cases/24 hours
- 4 Trauma beds; 4 recovery/intensive care beds
- Post-operative care; 8 patients (4 ventilated)/6 hours

Life-saving procedures

- Damage control surgery (DCS)
- Damage control resuscitation (DCR)
- General surgery
- Orthopedic stabilization

20-person team*

- 1 Orthopedic/3 General Surgeons
- 2 Nurse Anesthetists
- 3 Nurses: Emergency/Critical Care/Surgical
- 11 Technicians/Administrative Personnel

Supporting Medical Company

- X-ray, laboratory, Personnel, life support

*Teams may be “split” to support 2 geographic areas

Figure 1. US Army R2 Forward Surgical Team.

dedicated trauma registrars). Members of R2 teams received basic training on the database once deployed and entered data on a voluntary basis; R2 personnel did not receive formal data management training before deployment. When available, source documentation was used to validate and complete the R2R data entry by trained data abstractors at the JTS located at the US Army Institute of Surgical Research, San Antonio, TX; however, less than 10% of the R2R records have been thus verified. The R2R includes prehospital data: mechanism of injury (explosion, gunshot wound, crash, other), type of injury (blunt, penetrating, burn, other), protective equipment, location within Regional Command, mode of transport, time from point of injury to R2 facility, and prehospital interventions and some vital signs (systolic blood pressure, diastolic blood pressure, respiratory rate, temperature, pulse, O₂ saturation, Glasgow Coma Scale, etc). R2-related data elements include arrival and discharge: patient status (alive or deceased), time, vital signs, and some laboratory results. Diagnosis, interventions, blood administration, and some complications are also included.

Study Methods

Deidentified data in the R2R were retrospectively reviewed for patients who received treatment at R2 facilities and met the following inclusion criteria: 1) adult patients (defined as age 18 year or older at the time of injury); 2) injured in Afghanistan during OEF; 3) trauma eligible, defined as battle injury and nonbattle injury; and 4) injured between February 2008 and September 2014. Patients who did not meet trauma-eligible criteria (e.g., isolated disease, or psychological or mental illness/disorder) were excluded.

Variables for analysis included age in years at time of injury, sex, Regional Command location, prehospital emergency care and en route care provided, time from point of wounding to R2, arrival status (dead/alive), diagnosis, and discharge status (dead/alive). Time to arrival at R2 was further categorized to reflect the 2009 "Golden Hour directive" by time equal to or less or greater than 60 minutes, as well as time before and after June 15, 2009.²⁷ To control for significant variability in arrival times, time to R2 within 160 minutes (75th percentile) was selected for comparison of pre- and post-Golden Hour times overall and by patient's affiliation.

Statistical Analysis

Descriptive statistics were used to compare the study groups of interest. Casualties were categorized according to their affiliation as [1] US-Force (US Army, US Air Force, US Marine Corps, and US Navy), [2] US other (US civilian and contractors), [3] NATO coalition, [4] Afghan forces (Afghan military and Afghan police), [5] Afghan civilians, and [6] other (non-NATO coalition, non-US civilian, combatant, and other). Regional distribution was categorized by Regional Command (RC)-North, South, Southwest, West, and East. Mechanism of injury was categorized as [1] explosion, [2] gunshot wounded (GSW), [3] motor vehicle crash (MVC), [4] explosion-GSW, [5] explosion-MVC, [6] explosion-helicopter/plane crash, and [7] other. Type of injury was defined as penetrating and non-penetrating (blunt, penetrating, burn, other) injury. Chi-square or Fisher exact test, Student *t*-test or Mann-Whitney test, ANOVA, or Kruskal-Wallis test was used where appropriate.

RESULTS

A total of 15,404 patients were included in the R2R from February 2008 to September 2014; 12,849 patients (83%) met inclusion criteria (Fig. 2). Data availability included 100% demographic information, 33% en-route documentation, 99% diagnosis, and 98% mechanism of injury. Regional Command (RC) distribution was RC-East, 8,636 (67%); RC-South, 1,987 (16%); RC-Southwest, 1,158 (9%); RC-West, 894 (7%); and RC-North; 174 (1%).

Demographic and injury characteristics by affiliation are shown in Table 1, major patients' affiliations were US Force (36.4%) and Afghan Force (35.4%) followed by Afghan civilian (17%). Most patients were male (96.7%) with median age (interquartile range) of 25 (21–30) years. Battle injury was predominant (76.2%; Table 1 and Fig. 3). Overall, annual recorded casualties increased from year 2008 to the peak in 2011 then declined in number of both battle injury and nonbattle injury casualties (Fig. 3).

Mechanisms of injury are described in Figure 4, which demonstrated complex trauma injuries. The most common mechanisms of injuries were explosion (41%), gunshot wounds (24%), and more than two causes of injuries (e.g., explosion and GSW or explosion and MVC) was 4.4% (Table 1 and Fig. 4). Penetrating injury was predominant (52.3%), followed by blunt injury (31.3%); 7.4% of the patients sustained both penetrating and blunt injury (Table 1 and Fig. 4). Overall median (interquartile range) arrival time was 75 (41–160) minutes, time varied among group affiliation ($p < 0.0001$); time from injury until arrival to a R2 facility was less than 60 minutes for 43% of patients (Table 1). Of patients transported to R2 within 160 minutes (75th percentile), time was reduced overall after the Golden Hour initiative ($p = 0.02$). When compared by group affiliation, time after the initiative was consistently reduced for all groups except the US Force ($p = 0.28$). Dead upon R2 arrival was 1.3% ($n = 167$), and death on R2 discharge was 2.7% (342 of the 12,682 patients alive upon R2 arrival).

The R2R contains the following data for future analysis: 33.2% ($n = 4,266$) of patients had 10,802 documented prehospital interventions; 13.4% ($n = 1,724$) of patients had tourniquets; 15.6% ($n = 2,036$) of patients had 69,023 prehospital medications; and 52.1% ($n = 6,697$) of patients had 34,639 procedures performed at R2.

DISCUSSION

Although a dedicated R2R has been in place since 2008, no systematic evaluation of the data has been conducted. This analysis demonstrated variability based on group affiliation with regard to mechanism and type of injury, transport time, prehospital interventions, and death while at R2 facility. Without analysis of this information, military planners and medical leaders will be unable to best allocate R2 resources in future operations.

The best use of R2 assets within a developed theater of war remain undefined. In 2009, the Secretary of Defense mandated a trauma system capable of delivering casualties to surgical capability within 1 hour.²⁷ This resulted in a redistribution of medical evacuation (MEDEVAC) and surgical capabilities

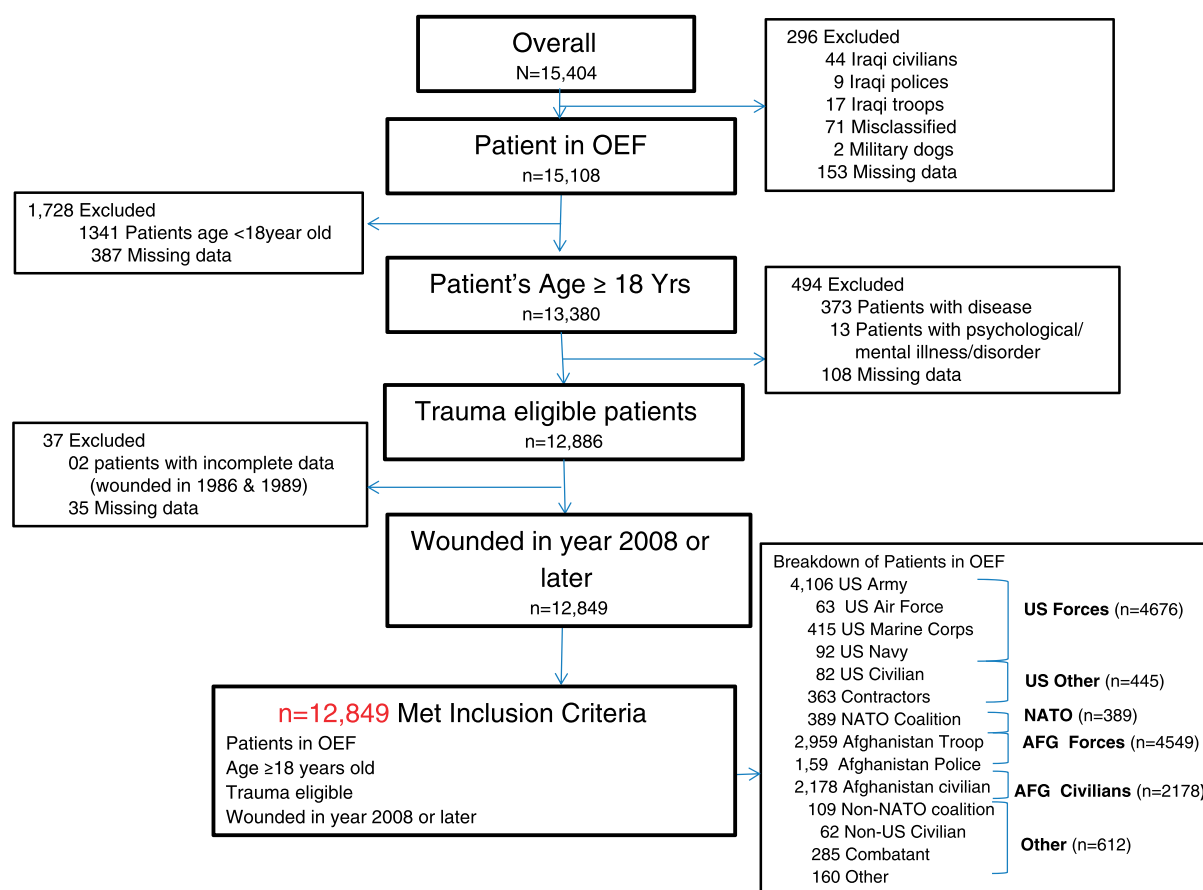


Figure 2. Included patients.

in theater, “splitting” of forward surgical teams, and automatic triage to the closest facility. While the mandate has been shown to have saved lives on the battlefield,²⁸ it is also important to consider historical civilian trauma experience that demonstrates that transporting severely injured patients to the closest facility is not always optimal, and direct transport to higher levels of care may improve outcomes.²⁹ Certainly, specifics of injury, time, distance, MEDEVAC, and R2 and R3 capabilities will affect outcomes within the trauma system. It is important that the evolution of the trauma system take into account such specific variables. A detailed analysis of R2 outcomes vis a vis capabilities will help provide evidence to inform further development of a deployed trauma system.

Because admission to a R3 facility was required for inclusion in the DoDTR until 2014, completeness of the R2R is unclear. Any patient treated at an R2 who did not subsequently transfer to a R3 hospital was not captured in the DoDTR until 2014. The DoDTR therefore excluded a significant number of patients treated at R2, including host nation casualties who were transferred directly to host nation facilities, patients returned to duty, and patients who died at the R2. Limited data directly reflecting the R2 experience is contained in the R2 database, albeit a convenience sample with almost no verification of accuracy. Additional exploration of both registries is required to identify patterns of missing information and improve capture of all patients treated at every role of care.

In addition to the JTS R2R, other sources of information exist that could be used to further characterize activities of R2 elements. The most extensive combat registry is the US DoDTR. This is the largest combat injury database in existence; it includes all services injury data derived from records with scoring of injuries, diagnoses and procedures, and patient outcomes. As of December 2015, there are 130,888 records that represent 79,795 unique patients (JTS, unpublished data, December 2015). Specialty modules and additional data sources include prehospital care, infectious diseases, blood transfusion, tactical evacuation times, ocular injury, outcomes, traumatic brain injury, acoustic injury, and en route care. The Armed Forces Medical Examiner Registry has information on all deaths in the combat theater and could inform analysis of died-of-wounds cases at R2 compared to R3. The US Navy and NATO allies (e.g., United Kingdom Joint Theater Trauma Registry) maintained robust registries, and the US Theater Medical Data Store contains source documentation of combat medical care. Unit and provider records are additional sources of valuable information regarding R2 treatment, particularly before the R2R development in 2008. Efforts are underway to incorporate all potential sources of R2 data into a comprehensive research data set.

Limitations to the JTS R2R include lack of data before the Registry implementation in 2008 and the voluntary nature of participation by R2 personnel to enter data. The members of the R2 teams did not receive the same level of training as

AQ2 TABLE 1. Demographic and Injury Characteristics of Patients in Study Data Set by Patient Affiliation.

	Overall	US Force	US Other	NATO	AFG Force	AFG Civilian	Other	p Value
Number of patients, n (%)	12,849	4,676 (36.4)	445 (3.5)	389 (3.0)	4,549 (35.4)	2,178 (16.9)	612 (4.8)	
Male, n (%)	12,418 (96.7)	4,513 (96.5)	423 (95.1)	381 (97.9)	4,498 (98.9)	2,005 (92.1)	598 (97.7)	<0.0001
Age, median (IQR), y	25 (21–30)	24 (22–29)	30 (25–41)	28 (24–32)	24 (21–28)	27 (22–35)	25 (21–31)	<0.0001
Battle injury, n (%)	9,792 (76.2)	3,637 (77.8)	275 (61.8)	282 (72.5)	3,658 (80.4)	1,417 (65.1)	523 (85.5)	<0.0001
Mortality status, n (%)								
Arrival (DOA)	167 (1.3)	63 (1.4)	5 (1.1)	10 (2.6)	62 (1.4)	23 (1.1)	4 (0.7)	0.14
Discharge (DOW)	342 (2.7)	63 (1.4)	8 (1.8)	3 (0.8)	154 (3.4)	96 (4.5)	18 (3.0)	<0.0001
Elapsed time from wounded to MTF, min								
Patients with time available, n (%)*	6,827 (53.1)	2,750 (58.8)	242 (54.4)	215 (55.3)	2,258 (49.6)	1,073 (49.3)	289 (47.2)	
Arrival time, median (IQR)	75 (41–100)	68 (40–140)	56 (20–120)	50 (33–110)	81 (45–157)	87 (48–210)	77 (40–185)	<0.0001
Patients with arrival time ≤ 60 min, n (%)**	2,934 (43.0)	1,267 (46.1)	132 (54.6)	134 (62.3)	880 (39.0)	399 (37.2)	122 (42.2)	<0.0001
Mechanism of injury, n (%)								<0.0001
Explosion	5,320 (41.4)	2,245 (48.0)	187 (42.0)	169 (43.4)	1,890 (41.5)	653 (30.0)	176 (28.8)	
GSW	3,082 (24.0)	632 (13.5)	61 (13.7)	69 (17.7)	1,355 (29.8)	682 (31.3)	283 (46.2)	
MVC	1,209 (9.4)	223 (4.8)	25 (5.6)	41 (10.5)	553 (12.2)	333 (15.3)	34 (5.6)	
Helicopter/plane crash	63 (0.5)	43 (0.9)	8 (1.8)	7 (1.8)	1 (0.01)	2 (0.1)	2 (0.3)	
Explosion-GSW	118 (0.9)	26 (0.6)	3 (0.7)	2 (0.5)	57 (1.3)	20 (0.9)	10 (1.6)	
Explosion-MVC	453 (3.5)	308 (6.6)	9 (2.0)	35 (9.0)	69 (1.5)	26 (1.2)	6 (1.0)	
Other	1,713 (13.3)	873 (18.7)	118 (26.5)	46 (11.8)	337 (7.4)	279 (12.8)	60 (9.8)	
Unknown/missing	891 (6.9)	326 (7.0)	34 (7.6)	20 (5.1)	287 (6.3)	183 (8.4)	41 (6.7)	
Type of injury, n (%)								<0.0001
Penetrating	6,714 (52.3)	1,788 (38.0)	196 (44.0)	168 (43.2)	2,830 (62.2)	1,302 (59.8)	440 (71.9)	
Penetrating and blunt	951 (7.4)	270 (5.8)	29 (6.5)	17 (4.4)	416 (9.1)	187 (8.6)	32 (5.2)	
Blunt	4,026 (31.3)	2,104 (45.0)	156 (35.1)	172 (44.2)	1,017 (22.4)	488 (22.4)	89 (14.5)	
Other	633 (4.9)	333 (7.1)	45 (10.1)	26 (6.7)	126 (2.8)	81 (3.7)	22 (3.6)	
Unknown/missing	525 (4.1)	191 (4.1)	19 (4.3)	6 (1.5)	160 (3.5)	120 (5.5)	29 (4.7)	
En-route intervention, n (%)	4,266 (33.2)	1,257 (26.9)	122 (27.4)	149 (38.3)	1,814 (39.9)	667 (30.6)	257 (42.0)	<0.0001
Tourniquet use, n (%)	1,724 (13.4)	596 (12.8)	43 (9.7)	56 (14.4)	659 (14.5)	263 (12.1)	107 (17.5)	0.0002

*Number (%) patients had elapsed time or arrival time defined as time (minutes) from point of injury (wounded) to R2 MTF available.

**Number (percent) of patients arrived to MTF within 60 minutes/total patients who had elapsed time available.

AFG, Afghanistan; DOA, dead on arrival; DOW, died of wounds; IQR, interquartile range; MTF, medical treatment facility; US, United States.

the DoDTR registrars, and entry into the Registry remains voluntary. The US Navy R2 teams supporting the US Marine Corps maintained a separate registry, and these data are not yet

integrated into the R2 research data set. Furthermore, the R2R is not and will not be directly linked with the larger DoDTR because it has not been validated against medical records. A significant shortcoming of the R2R is the lack of injury severity score and the inability to determine the most significant injury for patients with multiple documented injuries; future projects will ensure these scores and predominate injuries are linked with the DoDTR to facilitate meaningful analysis. There are limited transport time data before June 2009; thus, the trend toward improved US Force transport time was not statistically significant. During the course of the war, the Regional Command area of responsibility changed, most notably RC-South and RC-Southwest. Finally, and perhaps most importantly, because R2R use by deployed units was voluntary and inconsistent, there is no known denominator that would allow us to determine what proportion of R2 workload has actually been captured within the registry; thus, an unquantifiable but significant selection bias could exist.

This initial analysis of the R2R is intended as a prelude to a comprehensive review of various aspects of R2 care. For example, died-of-wounds rate, the patients who died while at the R2, was 2.7% in this analysis; the died-of-wounds rate in the DoDTR, comprised primarily of patients admitted to R3,

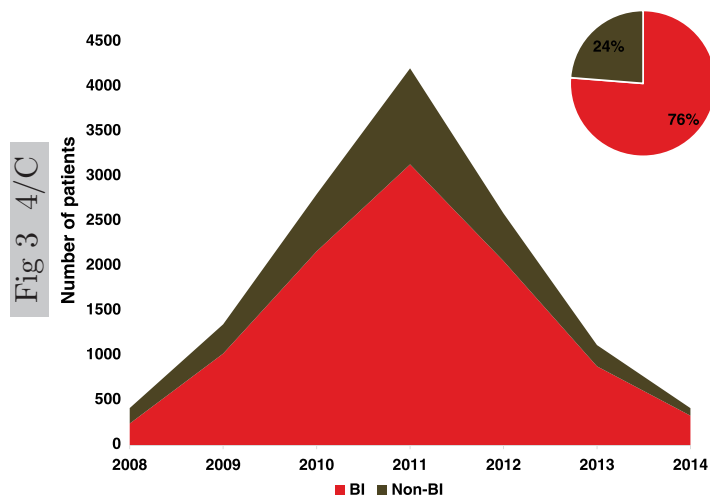


Figure 3. Battle injury (BI) compared to nonbattle injury (NBI) over time and as proportion of total.

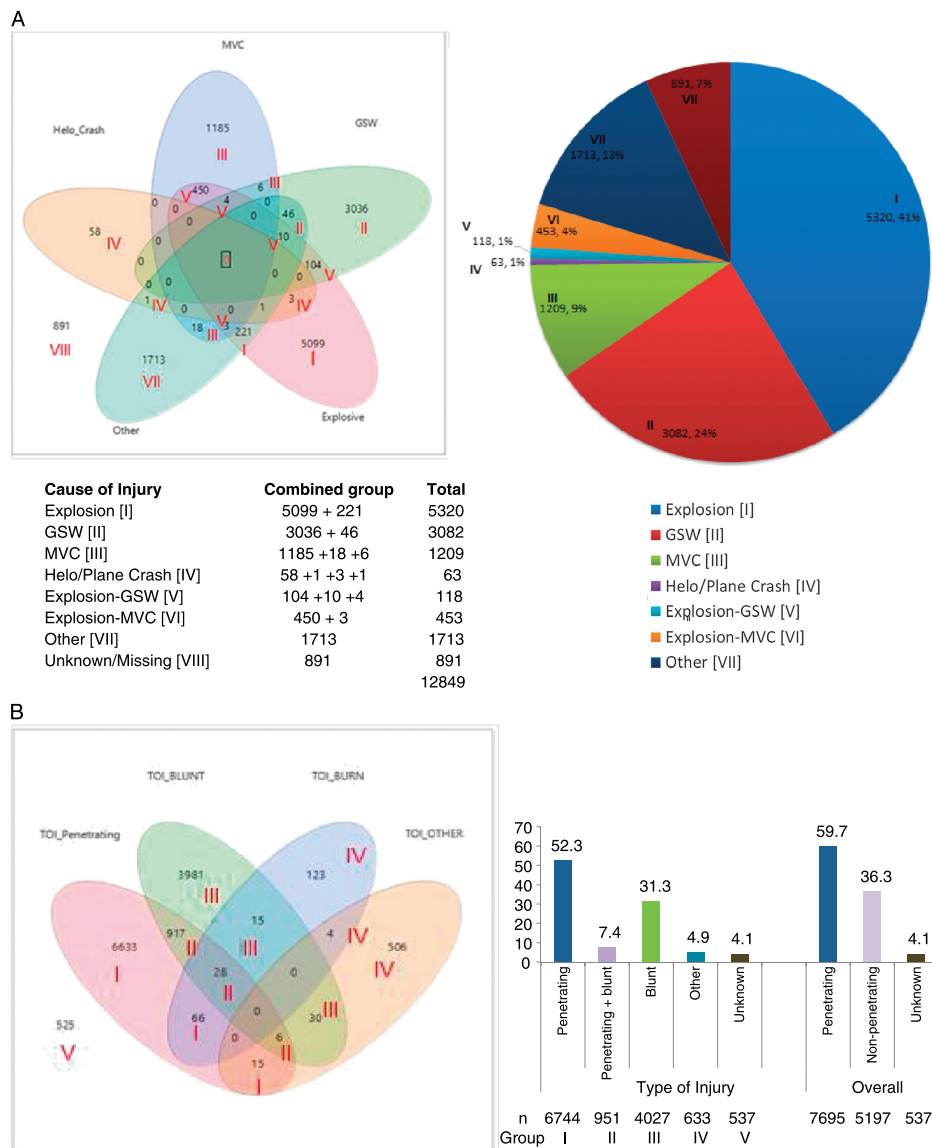


Figure 4. Mechanism (A) and type of injury (B). *Helo*, helicopter; *TOI*, type of injury.

was 2.2% (Unpublished data, DoDTR, 2015). Future analysis will carefully explore a range of outcomes for patients admitted to R2 compared to those who were admitted directly to an R3 following injury to identify whether significant differences exist between these groups. Efforts are ongoing to analyze specific populations (e.g., pediatrics, burns, brain-injured patients); differences in the mortality rates between US forces and others, perhaps due to personal protective equipment; interventions (e.g., tourniquet use, prehospital medications, and surgical procedures); effects of team training before deployment on quality of care, complications, and outcomes; and outcomes of R2 patients compared to similar patients admitted to R3 facility. The US Army is finalizing plans to adjust the composition of clinical specialty providers within the R2 Team, in particular, to include an emergency medicine physician; description of the surgical versus nonsurgical life and limb-saving interventions will provide objective support for this

change. Of particular interest is improvement of interoperability with our NATO partners to optimize combat casualty care. This project is part of the United Kingdom and US Service Personnel, Families and Veterans Task Force initiated at the direction of President Barak Obama and Prime Minister David Cameron in April 2011.

This evaluation of the R2R describes the patient's profile and common interventions performed at a sample of US R2 facilities in Afghanistan. Ongoing and detailed analysis of R2 information may provide evidence-based guidance to military planners and medical leaders to best allocate R2 resources in future operations and prepare teams for deployment.

AUTHORSHIP

E.A.M-S., T.D.L., J.A.B., Z.T.S., M.A.S., M.D.W., I.B.L., and K.R.G. contributed significantly to the design, data acquisition, analysis and interpretation of the data for this study. R.R. contributed significantly to the

design, and analysis and interpretation of the data for this study. S.A.S., T. H., S.C., and K.N.R. contributed significantly to the analysis and interpretation of the data for this study.

ACKNOWLEDGMENT

The authors thanks Dr Jean Orman, Ms Susan West, Mr Phil Sartin, Ms Inez Eddington, COL (Ret) John Kragh, Mr David Cannon, Mr Timothy Moore, Col Nigel Tai, LTC Jason Seery, and Lt Col Jennifer Hatzfeld for their support to this effort. The authors acknowledge the Joint Trauma System for providing data for this study.

DISCLOSURE

The authors declare no conflicts of interest. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense. The author(s) acknowledge the Department of Defense Trauma Registry (DoDTR) for providing data for this study. This study was presented at the 2015 Military Health System Research Symposium, August 17–20, 2015, in Ft Lauderdale, Florida.

REFERENCES

1. North Atlantic Treaty Organization. *AJP-4.10(A) Allied Joint Medical Support Doctrine*. 2006.
2. Eastridge BJ, Stansbury LG, Stinger H, Blackburne L, Holcomb JB. Forward surgical teams provide comparable outcomes to combat support hospitals during support and stabilization operations on the battlefield. *J Trauma*. 2009;66(4):S48–S50.
3. Schoenfeld AJ. The combat experience of military surgical assets in Iraq and Afghanistan: a historical review. *Am J Surg*. 2012;204(3):377–383.
4. Place RJ, Rush RM Jr, Arrington ED. Forward surgical team (FST) workload in a special operations environment: the 250th FST in Operation ENDURING FREEDOM. *Curr Surg*. 2003;60(4):418–422.
5. Rush RM Jr, Stockmaster NR, Stinger HK, Arrington ED, Devine JG, Atteberry L, Starnes BW, Place RJ. Supporting the Global War on Terror: a tale of two campaigns featuring the 250th Forward Surgical Team (Airborne). *Am J Surg*. 2005;189(5):564–570.
6. Peoples GE, Gerlinger T, Craig R, Burlingame B. Combat casualties in Afghanistan cared for by a single Forward Surgical Team during the initial phases of Operation Enduring Freedom. *Mil Med*. 2005a;170(6):462–468.
7. Peoples GE, Gerlinger T, Craig R, Burlingame B. The 274th Forward Surgical Team experience during Operation Enduring Freedom. *Mil Med*. 2005b;170(6):451–459.
8. Bilski TR, Baker BC, Grove JR, Hinks RP, Harrison MJ, Sabra JP, Temerlin SM, Rhee P. Battlefield casualties treated at Camp Rhino, Afghanistan: lessons learned. *J Trauma*. 2003;54(5):814–821.
9. Shen-Gunther J, Ellison R, Kuhens C, Roach CJ, Jarrard S. Operation Enduring Freedom: trends in combat casualty care by forward surgical teams deployed to Afghanistan. *Mil Med*. 2011;176(1):67–78.
10. Remick KN, Dickerson JA II, Cronk D, Topolski R, Nessen SC. Defining and predicting surgeon utilization at forward surgical teams in Afghanistan. *J Surg Res*. 2012;177(2):282–287.
11. Beilman GJ. Commentary on "Defining and predicting surgeon utilization at Forward Surgical Teams in Afghanistan". *J Surg Res*. 2013;185(1):E3–E4.
12. Vanfosson CA, Seery JM. Simultaneous surgeries in a split forward surgical team: a case study. *Mil Med*. 2011;176(12):1447–1449.
13. Becker T, Link M. Medical rules of engagement negative patients: the dilemma of forward surgical teams in counterinsurgency operations. *J Spec Oper Med*. 2011;11(2):12–15.
14. Vassallo DJ, Gerlinger T, Maholtz P, Burlingame B, Shepherd AF. Combined UK/US field hospital management of a major incident arising from a Chinook helicopter crash in Afghanistan, 28 Jan 2002. *J R Army Med Corps*. 2003;149(1):47–52.
15. Blackburne LH, Grathwohl KW, Barras P, Eastridge B. Maximizing patient thermoregulation in US Army forward surgical teams. *US Army Med Dep J*. 2008;60–66.
16. Nessen SC, Eastridge BJ, Cronk D, Craig RM, Berséus O, Ellison R, Remick K, Seery J, Shah A, Spinella PC. Fresh whole blood use by forward surgical teams in Afghanistan is associated with improved survival compared to component therapy without platelets. *Transfusion*. 2013;53(suppl 1):107S–113S.
17. Beitler AL, Jeanette JP, McGraw AL, Butera JR, Vanfosson CA, Seery JM. Emergency canine surgery in a deployed forward surgical team: a case report. *Mil Med*. 2011;176(4):477–480.
18. Stansbury LG, Lalliss SJ, Branstetter JG, Bagg MR, Holcomb JB. Amputations in U.S. military personnel in the current conflicts in Afghanistan and Iraq. *J Orthop Trauma*. 2008;22(1):43–46.
19. Chambers LW, Green DJ, Gillingham BL, Sample K, Rhee P, Brown C, Brethauer S, Nelson T, Narine N, Baker B, et al. The experience of the US Marine Corps' surgical shock trauma platoon with 417 operative combat casualties during a 12 month period of operation Iraqi Freedom. *J Trauma*. 2006;60(6):1155–1161; discussion, 1154–1161.
20. Chambers LW, Rhee P, Baker BC, Perciballi J, Cubano M, Compeggio M, Nace M, Bohman HR. Initial experience of US Marine Corps forward resuscitative surgical system during Operation Iraqi Freedom. *Arch Surg*. 2005;140(1):26–32.
21. Brethauer SA, Chao A, Chambers LW, Green DJ, Brown C, Rhee P, Bohman HR. Invasion vs insurgency: US Navy/Marine Corps forward surgical care during Operation Iraqi Freedom. *Arch Surg*. 2008;143(6):564–569.
22. Walker GJ, Zouris J, Galarneau MF, Dye J. Descriptive summary of patients seen at the surgical companies during Operation Iraqi Freedom-1. *Mil Med*. 2007;172(1):1–5.
23. Stevens RA, Bohman HR, Baker BC, Chambers LW. The U.S. Navy's forward resuscitative surgery system during Operation Iraqi Freedom. *Mil Med*. 2005;170(4):297–301.
24. Counihan TC, Danielson PD. The 912th forward surgical team in Operation New Dawn: employment of the forward surgical team during troop withdrawal under combat conditions. *Mil Med*. 2012;177(11):1267–1271.
25. Patel TH, Wenner KA, Price SA, Weber MA, Leveridge A, McAtee SJ. A U.S. Army forward surgical team's experience in Operation Iraqi Freedom. *J Trauma*. 2004;57(2):201–207.
26. Stinger H, Rush R. The Army forward surgical team: update and lessons learned, 1997–2004. *Mil Med*. 2006;171(4):269–272.
27. Gates RM. *Duty: Memoirs of a Secretary at War*. New York: Alfred A, Knopf; 2014.
28. Kotwal RS, Howard JT, Orman JA, Tarpey BW, Bailey JA, Champion HR, Mabry RL, Holcomb JB, Gross KR. The effect of a golden hour policy on the morbidity and mortality of combat casualties. *JAMA Surg*. 2015;1–10.
29. American College of Surgeons. *Resources for the Optimal Care of the Injured Patient*. Chicago, IL: American College of Surgeons; 2014.

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The Military Injury Severity Score: A better predictor of combat mortality than Injury Severity Score

AQ1 **Tuan Dinh Le, MD, DrPH, Jean A. Orman, ScD, MPH, Zsolt T. Stockinger, MD, Mary Ann Spott, PhD, Susan A. West, BSN, Elizabeth A. Mann-Salinas, PhD, Kevin K. Chung, MD, and Kirby R. Gross, MD, Fort Sam Houston, Texas**

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METHODS:

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The Military Injury Severity Score (mISS) was developed to better predict mortality in complex combat injuries but has yet to be validated.

US combat trauma data from Afghanistan and Iraq from January 1, 2003, to December 31, 2014, from the US Department of Defense Trauma Registry were analyzed. Military ISS, a variation of the ISS, was calculated and compared with standard ISS scores. Receiver operating characteristic curve, area under the curve, and Hosmer-Lemeshow statistics were used to discriminate and calibrate between mISS and ISS. Wilcoxon-Mann-Whitney, *t* test and χ^2 tests were used, and sensitivity and specificity calculated. Logistic regression was used to calculate the likelihood of mortality associated with levels of mISS and ISS overall.

Thirty thousand three hundred sixty-four patients were analyzed. Most were male (96.8%). Median age was 24 years (interquartile range [IQR], 21–29 years). Battle injuries comprised 65.3%. Penetrating (39.5%) and blunt (54.2%) injury types and explosion (51%) and gunshot wound (15%) mechanisms predominated. Overall mortality was 6.0%.

Median mISS and ISS were 5 (IQR, 2–10) vs. 5 (IQR, 2–10) but different in nonsurvivors, 30 (IQR, 16–75) vs. 30 (IQR, 16–75). Military ISS and ISS were discordant in 17.6% (*n* = 5,352), accounting for 17.6% of the total. For discordant severity scores, the median difference between mISS and ISS was 5 (IQR, 2–10) vs. 5 (IQR, 2–10) but different in nonsurvivors, 30 (IQR, 16–75) vs. 30 (IQR, 16–75). mISS shared 78% variability ($R^2 = 0.78$).

Area under the curve was higher in mISS than in ISS overall (0.82 vs. 0.79), for battle injury (0.79 vs. 0.76), non-battle injury (0.87 vs. 0.86), penetrating (0.81 vs. 0.77), blunt (0.77 vs. 0.75), explosion (0.81 vs. 0.78), and gunshot (0.79 vs. 0.73), all *p* < 0.001. Higher mISS and ISS were associated with higher mortality. Compared with ISS, mISS had higher sensitivity (81.2 vs. 63.9) and slightly lower specificity (80.2 vs. 85.7).

CONCLUSION:

Military ISS predicts combat mortality better than does ISS. (*J Trauma Acute Care Surg.* 2016;00: 00–00. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic and epidemiologic study, level III.

KEY WORDS: Combat mortality; mAIS; Military Abbreviated Injury Scale; Military Injury Severity Score; mISS.

Since it was introduced by Baker et al.¹ in 1974, the Injury Severity Score (ISS) has become the most commonly used anatomic scoring method for determining injury severity,² predicting mortality and morbidity,³ and as a tool for research and other applications (e.g., quality assurance).^{1,4} The ISS is defined as the sum of the squares of the highest Abbreviated Injury Scale (AIS) scores in each of the three most severely injured body regions (BRs).¹ The six BRs that are defined in the AIS are the head/neck; face; thorax; abdomen and pelvic contents; extremities; and external and burn. The most common cause of injury in the US military is combat, and the most common cause of injury in the US is motor vehicle accidents.^{5,6} and civilian

trauma tends to involve less complex injury patterns. Conversely, combat-related injuries, which are frequently caused by destructive explosions (e.g., improvised explosive devices) and other high-energy events, tend to be more complex and involve multiple body regions.¹¹ Because the ISS relies on only one body region, it may underestimate the true severity of injury in complex military trauma, both among and within BRs. Furthermore, the AIS and ISS are inadequate for describing penetrating injuries,^{6,12} which are frequently sustained in combat.⁶ The performance of the ISS in predicting the mortality of patients with blunt trauma is also limited as shown in the systematic review by Tohira et al.,¹³ in which the New Injury Severity Score was found to be superior to the ISS. Despite these limitations, the ISS is the most commonly used scoring system globally to quantify injury severity in both civilian and military trauma.^{14,15} To attempt to overcome limitations of the ISS, an expert panel of military trauma surgeons developed the Abbreviated Injury Severity Scale 2005–Military (mAIS).¹⁶ Since 2005, the mAIS has been used to calculate the Military Injury Severity Score (mISS). The mISS takes complex and multiple injuries into account, whereas ISS does not. However, the mISS has not been validated in the combat trauma populations for which it was designed.

Submitted: December 3, 2015, Revised: February 24, 2016, Accepted: February 24, 2016. From the Joint Trauma System (T.D.L., Z.T.S., M.A.S., S.A.W., K.R.G.), US Army Institute of Surgical Research (T.D.L., J.A.O., E.A.M.-S., K.K.C.), Fort Sam Houston, Texas. This study was presented at the 29th annual meeting of the Society of Military Surgeons of Trauma, January 9 to 12, 2016, in San Antonio, Texas. Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).

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J Trauma Acute Care Surg
Volume 00, Number 00

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Please replace "injury scores" for "ISS" here only

The objectives of this study were to (1) examine the discrepancies between military and civilian injury severity scoring systems using anatomic injury scales (mAIS vs. AIS) and mISS (mISS vs. ISS), (2) discriminate between the two injury severity scoring systems, and (3) determine whether the mISS is a superior injury severity scoring system for defining injury severity to compare treatment effects and injury outcomes (e.g., mortality) for combat trauma research and to inform trauma care process improvement. We hypothesized that the mAIS and mISS would be superior to the AIS/ISS in characterizing injury severity and predicting mortality in the combat-injured population.

PATIENTS AND METHODS

Patient Population

This performance improvement evaluation project was led by the Joint Trauma System at the US Army Institute of Surgical Research, Joint Base San Antonio–Fort Sam Houston, Texas. Data were extracted from the US Department of Defense Trauma Registry (DoDTR, [http://www.dodtr.mil](#)) prior to October 2014. The study population was composed of patients who sustained injury in the Iraq and Afghanistan theaters of operation from January 1, 2003, through December 31, 2014. Retrospective data for a total of 31,033 patients were reviewed. The final study population was composed of 30,364 patients who met all four of the following inclusion criteria: (1) had both mISS and ISS scores, (2) had arrival and discharge data, (3) had complete casualty classification (battle injury [BI] and non-battle injury [NBI]), and (4) had information about the type and mechanism of injury. Patients (n = 669; 2.2%) did not have (1) documented mISS and/or ISS (n = 118), (2) discharge status (n = 169), or (3) BI and/or NBI data (n = 382) (Fig. 1).

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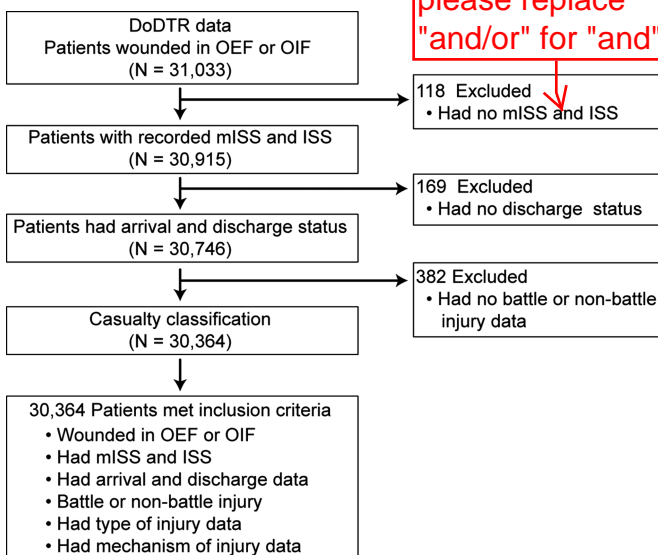


Figure 1. Study population and inclusion criteria. A total of 31,033 patients who were all US service members and wounded in Iraq (OIF) and Afghanistan (Operation Enduring Freedom) were recorded in the DoDTR. Of them, 30,364 patients met inclusion criteria for this study.

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Study Definitions

The ISS, an anatomically based ordinal scale developed by Baker et al.¹ in 1974, incorporates the sum of the squares of the three most severe AIS scores from among six different BRs: head/neck (BR1), face (BR2), thorax (BR3), abdomen and pelvic contents (BR4), extremities and shoulder and pelvic girdles (BR5), and external and burn (BR6). The AIS level of severity is graded using a scale from 1 to 6 (1 = minor, 2 = moderate, 3 = serious, 4 = severe, 5 = critical, 6 = maximal/currently untreatable). Calculated ISS ranges from 1 to 75. The ISS in this analysis was constructed by using the AIS 2005 criteria modified in 2005 and updated in 2008 (AIS). The mISS, a variation of the ISS developed in 2005 by an expert panel of military trauma surgeons, is calculated as the sum of the squares of the three most severe AIS 2005–Military criteria and updated in 2008 (mAIS).^{6,16} Severity in the mAIS is graded using the same scale from 1 to 6 as is used for the AIS, and mISS is also scored from 1 to 75; however, the severity scales are different between the two injury severity systems (Supplementary Table 2, Supplemental Digital Content/TA/A746).

Please replace "BI and NBI" with "battle injury (BI) and non-battle injury (NBI)"

Between mISS and civilian ISS were differences in values and dissimilar ISS values between systems (military vs. civilian). Both the mISS and ISS values were grouped into four categories as mild (scored 1–9), moderate (10–15), severe (16–24), and critical (≥25).²⁰ Discordance in injury severity level was defined as differences in injury severity categories between the two injury scoring systems as shown in Figure 2B. Casualty classifications were categorized as BI and NBI. Battle injury was defined as injury that occurred because of battle-related activities or hostile action, including travel to and from the activities, as well as any injury caused by improvised explosive devices and/or mortars. Non-battle injury was defined as any injury not directly attributable to hostile action or terrorist activity and/or self-inflicted injuries. The primary outcome was mortality defined as combat-related death that occurred prehospital or in-hospital, including killed in action (KIA), dead on arrival at a medical treatment facility (MTF), and died of wounds.

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Statistical Analysis

The values of mISS and ISS were extracted directly from the DoDTR data set and calculated using the AIS 2005–Military criteria and updated in 2008 (mAIS) for mISS and AIS 2005 criteria and updated in 2008 (AIS) for ISS. The patients were divided into two groups: those who died prehospital or in-hospital (nonsurvivors) and those who were alive at discharge from Role 2 or a higher level of care (survivors). The predictive performance of the mISS was compared with the ISS with mortality as the primary outcome. Analysis was first done on all patients, then by (1) subpopulations according to injury classification (BI or NBI), (2) by dominant injury type (penetrating or blunt), and (3) by dominant injury mechanism (explosion or gunshot wounds [GSWs]). The severity levels of mISS and ISS, categorized as mild (1–9), moderate (10–15), severe (16–24), and critical (≥25), were used to evaluate different associations with the likelihood of mortality between the two injury severity scoring systems. To compare sensitivity and specificity for predicting risk

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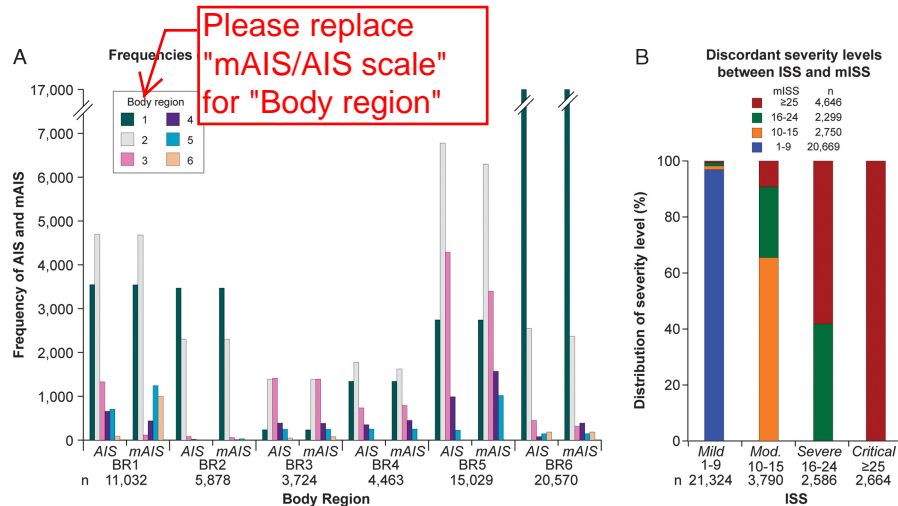


Figure 2. Discrepancies between the military and civilian injury scoring systems (mAIS vs. AIS and mISS vs. ISS) in 30,364 combat-related patients. (A) Different frequencies of the AIS by injured BR between the AIS 2005–Military criteria (mAIS) and the Civilian AIS 2005 criteria (AIS). Roman numerals (I–VI) represent different BRs (BR: BR1 (I, head/neck), BR2 (II, face), BR3 (III, thorax), BR4 (IV, abdomen and pelvic contents), BR5 (V, extremities, shoulder, and pelvic girdles), and BR6 (VI, external and burn). Greek numerals 1 to 6 represent six scales of the mAIS and AIS, with 1 = minor to 6 = maximal/currently untreatable. In this panel, 10% (n = 6,055) injuries had dissimilar AIS values, and most of these dissimilar values occurred in BR1 (I) and BR5 (V). (B) Discordant injury severity levels categorized as mild (1–9), moderate (10–15), severe (16–24), and critical (≥25 or 25–75) between the mISS and the civilian Injury Severity Score (ISS). The numbers of injuries (n) in each BR or injury severity levels are shown.

of mortality, the mISS and ISS values were dichotomized as less than 16 or 16 or greater (defined as severe injury).²¹

Descriptive statistics were performed using χ^2 or Fisher exact test for categorical variables and Wilcoxon–Mann–Whitney or *t* test for continuous variables where appropriate. The receiver operating characteristic (ROC) curve generated using univariate logistic regression was used to discriminate between mISS and ISS as predictors of combat-related mortality in the overall population and in subpopulations. The area under the ROC curve (AUC), which was used as an index of accuracy²² and the probability of correctly identifying the outcome of interest (e.g., mortality), was tested. The Hosmer–Lemeshow (H–L) goodness-of-fit test was used for calibration of the model between the mISS and ISS.^{22–24} The Akaike information criterion (AIC) was also used to compare the model of best fit. Sensitivity (the proportion of true positives) and specificity (the proportion of true negatives) were used to quantify the overall reliability and usefulness of mISS and ISS.

To determine whether mISS is a better predictor of mortality, logistic regression was used to estimate the likelihood (odds ratio [OR]) of mortality associated with mISS and ISS level among those who arrived at the MTF alive (n = 29,425). Covariates that influenced the likelihood of mortality were determined using univariate logistic regression (Supplementary Table 3, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>); specifically, each of the covariates found to be significantly associated with mortality in individual univariate (i.e., unadjusted) models was then included in the multivariate (adjusted) models. These covariates included gender, race/ethnicity, branch of service, casualty classification, theater of operation, year of injury, and physiologic parameters upon arrival at the MTF (e.g., pulse rate, respiratory rate, systolic blood pressure [SBP], and Glasgow Coma Scale [GCS]), as well as primary mechanism and type of injury.

Although missing rates for physiologic variables at arrival were small, 4.6% (pulse rate) to 11.8% (GCS) (Supplementary Table 4, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>), they were not missing at random, which has been shown to contribute to bias in studies of outcomes such as mortality. In our study, higher mortality rates were found among those with missing data versus those with data available: 18.9% vs. 2.2% for the pulse variable, 25.8% vs. 1.7% for the SBP variable, 19.8% vs. 0.9% for the respiratory variable; and 5.2% vs. 2.7% for the GCS variable, all *p* < 0.0001 (Supplementary Table 2, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>). Hence, the multiple imputation method recommended by Moore et al²⁵ may not be reliable.^{26,27} Furthermore, sensitivity analysis, which is recommended for missing data not at random, is also not reliable because in our study patients with complete data for all vital signs had lower mortality rate than did those with incomplete data, 0.8% versus 12.0% respectively, *p* < 0.0001 (Supplementary Table 2, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>). Therefore, to address the possibility of confounding due to missing data, we chose the simple approach of adjusting for them in the multivariate models by including them as a separate “missing” category.

Statistical significance was determined at the *p* < 0.05 level. Statistical analyses were performed using SAS, version 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

Study Population

For this study, we evaluated data from the DoDTR for 30,364 service members wounded in the Afghanistan (Operation Enduring Freedom) and Iraq (Operation Iraqi Freedom [OIF]) theaters of operation. A description of the study population is presented in Table 1. The majority of patients in this data

TABLE 1. Characteristics of the Patients and Their Combat-Related Injuries

Variable	All	Nonsurvivors	Survivors	<i>p</i>
No. of patients, n (%)	30,364	1,807 (6.0)	28,557 (94.0)	
Theater of operation, n (%)				<0.0001
Afghanistan	11,246 (37.0)	604 (33.4)	10,642 (37.3)	
Iraq	19,118 (63.0)	1,203 (66.6)	17,915 (62.7)	
Gender, n (%)				0.0005
Male	29,383 (96.8)	1,774 (98.2)	27,609 (96.7)	
Female	981 (3.2)	33 (1.8)	948 (3.3)	
Age at injury, median (IQR), y	24 (21–29)	24 (21–29)	24 (21–29)	0.15
Race/ethnicity, n (%)				<0.0001
White	11,809 (38.9)	885 (49.0)	10,924 (38.2)	
Black	1,764 (5.8)	116 (6.4)	1,648 (5.8)	
Hispanic	893 (2.9)	33 (1.8)	860 (3.0)	
Other/unknown	15,898 (52.4)	773 (42.8)	15,125 (53.0)	
Branch of service, n (%)				0.0002
US Army	22,480 (74.0)	1,358 (75.1)	21,122 (74.0)	
US Air Force	824 (2.7)	32 (1.8)	792 (2.8)	
US Marine Corps	6,237 (20.5)	391 (21.6)	5,846 (20.4)	
US Navy	823 (2.7)	26 (1.4)	797 (2.8)	
Casualty classification, n (%)				<0.0001
BI	19,840 (65.3)	1,597 (88.4)	18,243 (63.9)	
NBI	10,524 (34.7)	210 (11.6)	10,314 (36.1)	
Primary mechanism of injury, n (%)				<0.0001
Explosion	15,414 (50.8)	1,127 (62.4)	14,287 (50.0)	
Gunshot wounds	4,447 (14.6)	475 (26.3)	3,972 (13.9)	
Vehicle crash	2,196 (7.2)	82 (4.5)	2,114 (7.4)	
Helicopter/plane crash	267 (0.9)	38 (2.1)	229 (0.8)	
Other/unknown	8,040 (26.5)	85 (4.7)	7,955 (27.9)	
Dominant BR (BR), n (%)				
Head/neck (BR1)	11,030 (36.3)	803 (44.4)	10,227 (35.8)	<0.0001
Face (BR2)	5,878 (19.4)	204 (11.3)	5,674 (19.9)	<0.0001
Thorax (BR3)	3,724 (12.3)	343 (19.0)	3,381 (11.4)	<0.0001
Abdomen (BR4)	4,463 (14.7)	300 (16.6)	4,163 (11.6)	0.02
Extremities (BR5)	15,029 (49.5)	533 (29.5)	14,496 (50.8)	<0.0001
External (BR6)	20,570 (67.7)	1,101 (60.9)	19,469 (68.2)	<0.0001
Primary type of injury, n (%)				<0.0001
Penetrating	11,986 (39.5)	1,224 (67.7)	10,762 (37.7)	
Blunt	16,471 (54.2)	448 (24.8)	16,023 (56.1)	
Burn	998 (3.3)	88 (4.9)	910 (3.2)	
Other/unknown	909 (3.0)	47 (2.6)	862 (3.0)	
ISS, median (IQR)				
Civilian (ISS)	5.0 (2.0–10.0)	24 (9–33)	5 (2–10)	<0.0001
Military (mISS)	5.0 (2.0–13.0)	30 (16–75)	5 (2–10)	<0.0001

The *p* values were calculated with the use of a χ^2 , *t* test, or Wilcoxon-Mann-Whitney test as appropriate.

set were from OIF (63.0%). Most of the patients were male (96.8%) with a median age of 24 years (interquartile range [IQR], 21–29 years). Among patients with data available for race/ethnicity, white was predominant (38.9%); however, for more than half of the study population (53.0%), this variable was categorized as “other/missing.” Battle-related injuries accounted for 65.3% of total casualties. The most common mechanisms of injury were explosion (50.8%) and GSWs (14.6%) (Table 1). The leading injury types were blunt (54.2%) and penetrating (39.5%). The most common injured BRs were external and burn (67.7%), extremities (49.5%), and head/neck (36.3%) (Table 1).

The median mISS and ISS were 5 (IQR, 2–13) and 5 (IQR, 2–10) overall, 5 (IQR, 2–10) and 5 (IQR, 2–10) among survivors, and 30 (IQR, 16–75) and 24 (IQR, 9–33) in nonsurvivors, respectively (Table 1). Overall mortality in this cohort, including KIA, dead on arrival at an MTF, and died of wounds, was 6.0% (*n* = 1,807) (Table 1).

Discrepancies Between the Military and Civilian Injury Scoring Systems

Dissimilar values between the two abbreviated injury scale systems, mAIS and AIS, are shown in Figure 2A and

Supplementary Figure 1, A–D (Supplemental Digital Content 1, <http://links.lww.com/TA/A746>). A total of 60,668 AIS measures, defined as the maximum severe injury score for each BR, were captured from the entire cohort. Compared with the AIS, 10.0% (n = 6,055) of mAIS values were discrepant, including 8.2% with a mAIS score that was one level of severity higher than the AIS score, for example, AIS = 1 (mild) and mAIS = 2 (moderate), and 1.8% with a score two levels of severity higher (Supplementary Figure 1A, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>). Most of these mAIS and AIS differences occurred in BR I (head/neck) and BR V (extremities/pelvic and shoulder girdle), 23.4% and 17.5%, respectively (Supplementary Figure 1B, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>). Within BR I, 13.9% (n = 1,528) of mAIS scores were one level of severity higher, and 9.5% (n = 1,048) were two levels higher. Within BR V, 17.3% (n = 2,600) of mAIS scores were one level of severity higher, and 0.2% (n = 26) were two levels higher. Among the remaining BRs, within BR IV (abdomen/pelvic contents), 5.7% (n = 253) of mAIS scores were one level of severity higher than ISS, whereas the rest of the BRs had only small changes ranging from 0.5% to 2.7% (Supplementary Figure 1C, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>). These incremental mAIS changes resulted in increases in the anatomic injury score. For example, with civilian AIS at the critical level (AIS = 6), the proportion of patients with mAIS at the critical level was 4.9% higher (11.3% [n = 1,245] vs. 6.4% [n = 705]), and the proportion of patients at the “untreatable” level was 7.3% higher (9.1% [n = 1,002] vs. 0.8% [n = 90]). In BR V, the proportion with severity at the critical level (severity = 5) was 5.3% greater for mAIS versus civilian AIS (6.8% [n = 1,020] vs. 1.5% [n = 229], respectively). Smaller changes in mAIS were observed in the remaining BRs (Figure 2A and Supplementary Figure 1D, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>).

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"7.3%" by "8.3%"

Discrepancy Between mISS and ISS Severity Levels

The mISS and ISS shared 78% variability ($R^2 = 0.78$). Overall, 17.6% (n = 5,352) of patients showed discordant

severity scores between mISS and ISS with the median difference between the mISS and ISS of 9 (IQR, 7–16); range, 1 to 59.

Within the category of ISS scores from 1 to 9 (mild), 3.1% (n = 655) had discordant mISS severity scores, including 1.3% with mISS of 10 to 15 (moderate), 1.2% with mISS of 16 to 24 (severe), and 0.6% with mISS of 25 or greater (critical). Within the ISS category of scores from 10 to 15, 34.5% (n = 3,795) had discordant severity scores in mISS, including 25.2% with mISS of 16 to 24, and 9.3% with mISS of 25 or greater. Among patients with ISS severity scores of 16 to 24, 58.2% (n = 2,586) had discordant severity scores classified by mISS as 25 or greater. All patients with ISS of 25 or greater were categorized in mISS within the critical severity level (≥ 25) (Fig. 2B). Patients within the critical severity level (≥ 25) of mISS included 2.7% with mild ISS scores (1–9), 7.6% with moderate ISS scores (10–15), 32.4% with severe ISS scores (16–24), and 57.3% with critical ISS scores (≥ 25) (Supplementary Figure 2A, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>).

ROC for Mortality: Comparison Between mISS and ISS

The overall mortality rate was 6.0% (n = 1,807) (Table 1). A total of 82.4% (n = 25,012) of patients had similar mISS and ISS scores, accounting for 43.8% (n = 791) of all deaths, with a mortality rate of 3.2%. However, 17.6% (n = 5,352) of patients had discordant mISS and ISS scores, accounting for the remaining 56.2% (n = 1,016) of all deaths, with a mortality rate of 19.8%. Compared with the concordance of mISS versus ISS, discordance of mISS versus ISS was associated with higher mortality (Supplementary Figure 2B, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>).

Figure 3 illustrates that the AUC was significantly higher for mISS than for ISS overall (0.82 vs. 0.79) (Fig. 3, A and B), by casualty classification: BI (0.79 vs. 0.76) and NBI (0.87 vs. 0.86), by type of injury: penetrating (0.81 vs. 0.77) and blunt (0.77 vs. 0.75), and by mechanism of injury: explosion (0.81 vs. 0.78) and GSWs (0.79 vs. 0.73), all $p < 0.001$ (Fig. 3B). Overall and for each subpopulation, the mISS had an AUC value that was 1.0% to 6.0% higher than the corresponding ISS. Using

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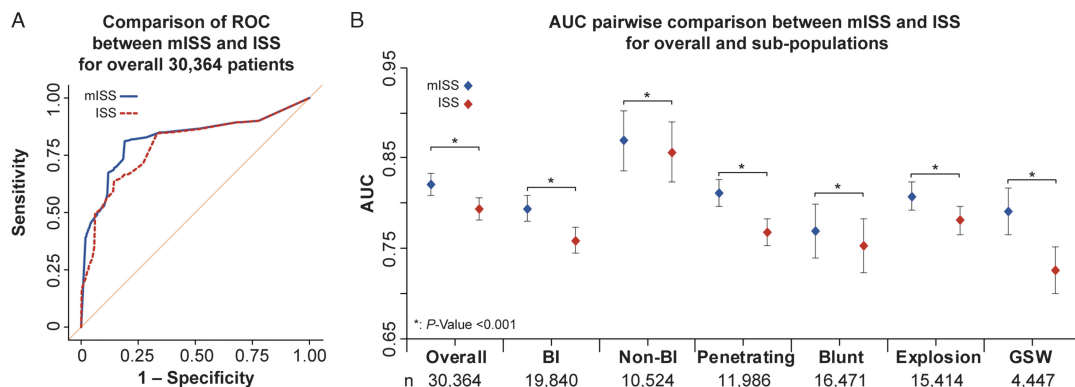


Figure 3. Receiver operating characteristic curve for mortality comparison between mISS and ISS. (A) A comparison of ROC between mISS and ISS for mortality in the overall patient population (n = 30,364). Overall AUCs for mISS and ISS are shown. (B) AUC pairwise comparisons between mISS and ISS for overall and subpopulations, regarding casualty classification (BI vs. NBI), type of injury (penetrating vs. blunt), and mechanism of injury (explosion vs. GSWs). The number of patients in each subpopulations and p values are shown.

mISS or ISS of 16 or greater as an indicator of severe injury, compared with ISS, overall mISS had a higher sensitivity (81.2 vs. 63.9) and slightly lower specificity (80.2 vs. 85.7).

The mISS as a Predictor of Combat-Related Mortality

Individuals with ISS (mISS and ISS) of 1 to 9 (mild) were used as the reference group in all models. Results are shown in Table 2. In the univariate analyses, among all those who arrived at an MTF alive ($n = 29,425$), both mISS and ISS severity levels were directly associated with a higher risk of mortality, and with the exception of mISS of 10 to 15 versus 1 to 9, the risk increased with increasing level of severity in all models, all $p < 0.0001$.

In multivariate models adjusted for possible confounding factors identified in the univariate analysis, compared with the mild severity level (1–9) in the mISS system, incrementally higher mISS injury levels were also independently associated with a higher likelihood of mortality by approximately 4-fold (OR, 3.66; 95% confidence interval [CI], 2.04–6.57), approximately 10-fold (OR, 10.48; 95% CI, 6.87–15.99), and 24-fold (OR, 24.16; 95% CI, 16.80–34.74) for moderate (10–15), severe (16–24), and critical (≥ 25), respectively. Similarly in the ISS system, incrementally higher ISS severity levels were also associated with a higher likelihood of mortality by approximately 5-fold (OR, 4.77; 95% CI, 3.16–7.20), approximately 7-fold (OR, 6.87; 95% CI, 4.67–10.09), and 18-fold (OR, 18.01; 95% CI, 12.66–25.60) for moderate (10–15), severe (16–24), and critical (≥ 25), respectively.

The AIC, a measure of the relative quality of a statistical model, showed the mISS system was better than the ISS system in both the univariate models (6,078 vs. 6,200) and the multivariate models (3,136 vs. 3,210) (Table 2). The H-L goodness-of-fit test used for calibration of the model also showed that the mISS system was better, especially in the multivariate models (10.46 [$p = 0.23$] vs. 15.08 [$p = 0.06$]) (Table 2).

DISCUSSION

In modern warfare, injuries are often caused by destructive explosions and other high-energy weapons and tend to be

complex and involve multiple BRs. Conversely, injuries in the civilian population, which most often occur as a result of blunt and motor vehicle traffic-related incidents and falls, tend to involve fewer BRs. The AIS 2005–Military was developed as an adaptation of AIS 2005 in recognition of the differences in the epidemiology, nature and severity of military-associated wounds compared with civilian injuries.¹⁶ However, the military injury scoring systems (mAIS and mISS) have not been implemented and institutionalized in the routine analysis of combat casualty care data. Our study validates the AIS 2005–Military, as proposed in 2010 as applied to the military population in the DoDTR, as a predictor of mortality in combat casualties. The mISS calculated using the AIS 2005–Military takes complex and multiple injuries within a single BR into account, whereas ISS does not address these important differences.

In the current study, the AIS 2005–Military was used to score more than 30,000 casualties with injuries incurred in theaters of operations. There are three main findings in this study. First, there are major anatomic severity scale (AIS) discrepancies between mISS and ISS, especially in BR I (head/neck, 23.4%) and BR V (extremities/shoulder and pelvic girdle, 17.5%). The mISS takes complex and multiple injuries into account, whereas ISS underestimates injury severity,²⁸ especially in BRs I and V.

Second, results of the ROC analysis confirmed that mISS has better discriminative ability than ISS for the prediction of mortality. Both better discrimination and goodness of fit of the models with mISS versus ISS were observed overall and within all of the subpopulations assessed: by casualty classification (BI vs. NBI), type of injury (penetrating vs. blunt), and mechanisms of injury (explosion vs. GSW). Specifically, greater discrimination for mISS versus ISS was observed for BI (0.79 vs. 0.76), penetrating (0.81 vs. 0.77), and GSWs (0.79 vs. 0.73), and lesser discrimination was found in the remaining subpopulations, especially for NBI (0.87 vs. 0.86).

Third, the results in this study indicate that the mISS is a better predictor of combat-related mortality than ISS. The use of the mISS in predicting mortality may be a more appropriate approach to quantify injury severity and patterns associated with mortality. This in turn may facilitate

TABLE 2. Likelihood of Mortality in Combat-Related Patients by Injury Severity Level Among Those Who Arrived at a Medical Treatment Facility Alive ($n = 29,425$)

	mISS				ISS			
	Univariate		Multivariate*		Univariate		Multivariate*	
	OR (95% CI)	<i>p</i>	OR (95% CI)	<i>p</i>	OR (95% CI)	<i>p</i>	OR (95% CI)	<i>p</i>
Severity level**								
10–15	1.27 (0.80–2.02)	0.32	3.66 (2.04–6.57)	<0.0001	2.24 (1.70–2.95)	<0.0001	4.77 (3.16–7.20)	<0.0001
16–24	8.82 (6.80–11.45)	<0.0001	10.48 (6.87–15.99)	<0.0001	6.78 (5.41–8.49)	<0.0001	6.87 (4.67–10.09)	<0.0001
≥ 25	29.34 (24.11–5.71)	<0.0001	24.16 (16.80–34.74)	<0.0001	30.56 (25.59–36.48)	<0.0001	18.01 (12.66–25.60)	<0.0001
Model fit								
AIC	6,078		3,136		6,200		3,210	
H-L goodness-of-fit test	<0.001	0.99	10.46	0.23	<0.001	0.99	15.08	0.06

*All multivariate models were adjusted for gender, race/ethnicity, military rank, branch of service, casualty classification, theaters of operation, and physiologic parameters upon arrival at the MTF, including pulse rate, respiratory rate, SBP, and GCS, as well as the primary mechanism and type of injury.

**Injury severity level: the mISS and ISS values were grouped into four categories as mild (scored 1–9), moderate (10–15), severe (16–24), and critical (≥ 25). The category of mild (1–9) was used as a reference group.

performance improvement aimed at reducing mortality and morbidity in the military combat trauma population by providing more appropriate interventions.

This study assessed AIS 2005–Military for mortality only. Civilian AIS has also been validated as a predictor of morbidity and length of stay.^{29–33} AIS 2005–Military, however, has not been assessed for these outcomes. In order to validate mISS for morbidity in our study population, further queries of the DoDTR will be needed to obtain the necessary data. With regard to length of stay, comparison of military and civilian findings will be challenging. In the military trauma care setting, the movement of patients across levels of care from theater to stateside and through multiple treatment facilities will impact length of stay differently than transfers from one facility to another in the civilian setting.

Our study has some limitations. First, because the DoDTR relies primarily on abstraction of medical records, not all casualties were included. In particular, KIAs could be missing from the data set. This may have contributed to the lower overall mortality rate in our study (6%) compared with that published in a Department of Defense report (10%).³⁴ Because, KIAs are among the most severely injured individuals with very complex injury patterns, their exclusion suggests that our findings that mISS is superior to ISS in characterizing the severity of more complex injuries are likely conservative. Second, we had some missing data, especially for physiologic variables measured at arrival (Supplementary Table 2, Supplemental Digital Content 1, <http://links.lww.com/TA/A746>). However, because the rates of missing data were low, and we adjusted for missing values in the multivariate statistical models, missing data likely did not greatly impact our findings. Third, the differences in AUCs between mISS and ISS, although statistically significant, were marginally different, indicating that both have prognostic and clinical advantages. Finally, mISS has a slightly lower specificity in mISS (fewer missed mortality cases/false negative) outweighs the lower specificity (slightly greater number of false positives) in predicting mortality. Finally, because the data were not available, we were unable to compare the mISS with the New Injury Severity Score (reference). Future studies should also compare the mISS to this measure.

Our study validates the usefulness of mISS in predicting injury severity among combat wounds. The development of the mISS for use in the AIS 2005–Military effort to further improve injury severity scoring for combat-related injury. Thus, the mISS would be a more effective tool than ISS for use in a research to evaluate outcomes of interest in combat casualty care (e.g., mortality, hospital length of stay, and complications). Our results suggest that even for NBI AIS 2005–Military was a better measure of severity. The next step in evaluating the ability of mISS to characterize more complex injury patterns will involve applying it to a population of civilian casualties to determine if it is also a better measure of injury severity for noncombat injuries.

CONCLUSIONS

The present study validates the superiority of the mISS over the civilian-derived ISS in providing better discriminatory

ability to predict mortality in the military trauma population overall and within subpopulations with regard to injury classification, injury type, and mechanisms of injury.

AUTHORSHIP

T.D.L. and K.R.G. conceived the study and designed the project. T.D.L. performed data analysis. J.A.O., Z.T.S., M.A.S., E.A.M.-S., K.K.C., and K.R.G. oversaw the project and provided epidemiologic and clinical context. S.A.W. and M.A.S. obtained data for analysis. T.D.L. and K.R.G. drafted the manuscript, to which all authors have contributed to critical revision. All authors reviewed the manuscript.

ACKNOWLEDGMENT

The authors acknowledge DoDTR and the Patient Administration Systems & Biostatistics Activity for providing data for this study. The authors also acknowledge the Joint Trauma System Role 2 Registry Team, Dr. Edward Mazuchowski, and Mr. Michael Galameau for their support for this study. The authors also acknowledge Lingamanaidu Ravichandran, Ph.D., for editing and proofreading this manuscript.

DISCLOSURE

The authors declare no conflicts of interest. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

REFERENCES

1. Baker SP, O'Neill B, Haddon W Jr, Long WB. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14(3):187–196.
2. Osler T, Baker SP, Long W. A modification of the Injury Severity Score that both improves accuracy and simplifies scoring. *J Trauma*. 1997;43(6):922–925 discussion 925–6.
3. Osler T, Glance L, Buzas JS, Mukamel D, Wagner J, Dick A. A trauma mortality prediction model based on the anatomic injury scale. *Ann Surg*. 2008;247(6):1041–1048.
4. Kim YJ. Injury severity scoring systems: a review of application to practice. *Nurs Crit Care*. 2012;17(3):138–150.
5. Centers for Disease Control and Prevention. *Ten Leading Causes of Injury Charts*. 2015. Available at http://www.cdc.gov/injury/wisqars/overview/key_data.html. Accessed November 19, 2015.
6. Lawnick MM, Champion HR, Gennarelli T, Galameau MR, D'Souza E, Vickers RR, Wing V, Eastridge BJ, Young LA, Dye J, Spott MA, Jenkins DH, Holcomb J, Blackbourne LH, Ficke JR, Kalin EJ, Flaherty S. Combat injury coding: a review and reconfiguration. *J Trauma Acute Care Surg*. 2013;75(4):573–581.
7. Smurr LM, Robinson M, Smith-Forbes E. Treating the war casualty: case reports of polytrauma. *J Hand Ther*. 2008;21(2):177–187; quiz 188.
8. Dominguez F, Beekley AC, Huffer LL, Gentlesk PJ, Eckart RE. High-velocity penetrating thoracic trauma with suspected cardiac involvement in a combat support hospital. *Gen Thorac Cardiovasc Surg*. 2011;59(8):547–552.
9. Popivanov G, Mutafchiyski VM, Belokonski EI, Parashkevov AB, Koutin GL. A modern combat trauma. *J R Army Med Corps*. 2014;160(1):52–55.
10. Fleming M, Waterman S, Dunne J, D'Alleyrand JC, Andersen RC. Dismounted complex blast injuries: patterns of injuries and resource utilization associated with the multiple extremity amputee. *J Surg Orthop Adv*. 2012;21(1):32–37.
11. Beckett A, Pelletier P, Mamczak C, Benfield R, Elster E. Multidisciplinary trauma team care in Kandahar, Afghanistan: current injury patterns and care practices. *Injury*. 2012;43(12):2072–2077.
12. Smith BP, Goldberg AJ, Gaughan JP, Seamon MJ. A comparison of Injury Severity Score and New Injury Severity Score after penetrating trauma: a prospective analysis. *J Trauma Acute Care Surg*. 2015;79(2):269–274.
13. Tohira H, Jacobs I, Mountain D, Gibson N, Yeo A. Systematic review of predictive performance of injury severity scoring tools. *Scand J Trauma Resusc Emerg Med*. 2012;20:63.

14. Lavoie A, Moore L, LeSage N, Liberman M, Sampalis JS. The Injury Severity Score or the New Injury Severity Score for predicting intensive care unit admission and hospital length of stay? *Injury*. 2005;36(4):477–483.
15. Rutledge R, Hoyt DB, Eastman AB, Sise MJ, Velky T, Canty T, Wachtel T, Osler TM. Comparison of the Injury Severity Score and ICD-9 diagnosis codes as predictors of outcome in injury: analysis of 44,032 patients. *J Trauma*. 1997;42(3):477–487; discussion 487–9.
16. Champion HR, Holcomb JB, Lawnick MM, Kelliher T, Spott MA, Galarneau MR, Jenkins DH, West SA, Dye J, Wade CE, Eastridge BJ, Blackbourne LH, Shair EK. Improved characterization of combat injury. *J Trauma*. 2010;68(5):1139–1150.
17. Blackbourne LH, Grathwohl K, Eastridge B, MacDonald DL, Holcomb JB. Optimizing transport of postoperative damage control patients in the combat zone. *US Army Med Dep J*. 2007;11–16.
18. Eastridge BJ, Jenkins D, Flaherty S, Schiller H, Holcomb JB. Trauma system development in a theater of war: experiences from Operation Iraqi Freedom and Operation Enduring Freedom. *J Trauma*. 2006;61(6):1366–1372 discussion 1372–3.
19. Blackbourne LH, Baer DG, Eastridge BJ, Butler FK, Wenke JC, Hale RG, Kotwal RS, Brosch LR, Bebart VS, Knudson MM, Ficke JR, Jenkins D, Holcomb JB. Military medical revolution: military trauma system. *J Trauma Acute Care Surg*. 2012;73(6 Suppl 5):S388–S394.
20. American College of Surgeons. Resources for optimal care of the injured patient 2014. Available at: <https://www.facs.org/quality-programs/trauma/vrc/%20resources>. Accessed February 5, 2016.
21. Demetriades D, Martin M, Salim A, Rhee P, Brown C, Doucet J, Chan L. Relationship between American College of Surgeons trauma center designation and mortality in patients with severe trauma (Injury Severity Score > 15). *J Am Coll Surg*. 2006;202(2):212–215 quiz A245.
22. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*. 1982;143(1):29–36.
23. Hanley JA, McNeil BJ. A method of comparing the areas under receiver operating characteristic curves derived from the same cases. *Radiology*. 1983;148(3):839–843.
24. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics*. 1988;44(3):837–845.
25. Moore L, Hanley JA, Turgeon AF, Lavoie A, Emond M. A multiple imputation model for imputing missing physiologic data in the national trauma data bank. *J Am Coll Surg*. 2009;209(5):572–579.
26. Li P, Stuart EA, Allison DB. Multiple imputation: a flexible tool for handling missing data. *JAMA*. 2015;314(18):1966–1967.
27. Moore L, Hanley JA, Lavoie A, Turgeon A. Evaluating the validity of multiple imputation for missing physiological data in the national trauma data bank. *J Emerg Trauma Shock*. 2009;2(2):73–79.
28. Shin E, Evans KN, Fleming ME. Injury severity score underpredicts injury severity and resource utilization in combat-related amputations. *J Orthop Trauma*. 2013;27(7):419–423.
29. Gabbe BJ, Cameron PA, Wolfe R, Simpson P, Smith KL, McNeil JJ. Predictors of mortality, length of stay and discharge destination in blunt trauma. *ANZ J Surg*. 2005;75(8):650–656.
30. Dick WF, Baskett PJ. Recommendations for uniform reporting of data following major trauma—the Utstein style. A report of a working party of the International Trauma Anaesthesia and Critical Care Society (ITACCS). *Resuscitation*. 1999;42(2):81–100.
31. Bull JP. Measures of severity of injury. *Injury*. 1978;9(3):184–187.
32. Timmons SD, Bee T, Webb S, Diaz-Arrastia RR, Hesdorffer D. Using the abbreviated injury severity and Glasgow Coma Scale scores to predict 2-week mortality after traumatic brain injury. *J Trauma*. 2011;71(5):1172–1178.
33. McKee MD. Abbreviated Injury Scale does not reflect the added morbidity of multiple lower extremity fractures. *J Trauma*. 1997;42(2):347–348.
34. Gawande A. Casualties of war—military care for the wounded from Iraq and Afghanistan. *N Engl J Med*. 2004;351(24):2471–2475.

AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES

AQ1 = Please check if authors name are correctly captured for given names (in red) and surnames (in blue) for indexing after publication.

AQ2 = Please provide location of Joint Trauma System.

AQ3 = Is location indicated for US Army Institute of Surgical Research correct? Please check.

END OF AUTHOR QUERIES

Evaluation of Healthcare Systems Training for Combat Casualty Care (CCC) Skills

Pre-Deployment Training Survey

The purpose of this study is to evaluate overall Healthcare Systems Training for combat casualty care, including individual and team training in a Deployed Hospital Care (DHC) setting, as conducted by the United Kingdom (UK) and the United States (US) deployment and pre-deployment teams. This research aims to provide evidence based analysis of Healthcare Systems Training outcomes in deployed hospital care to allow the Defense Health Agency (DHA) to formulate policies, procedures and guidelines for the employment of healthcare medical assets in present and future conflicts. It will allow policy makers to consider doctrine, organization, training, leadership, material, and safety (DOTLMS) principles in determining the most efficient and effective use of those assets and will assist operational and medical commanders in preparing those assets for employment.

Your survey responses are valuable to this effort. Your participation is greatly appreciated.

Inclusion criteria and consent:

1. Are you 18 years of age or older?
 - a. Yes
 - b. No
2. Are you prior or current US Army, Reserve and/or Active Duty?
 - a. Yes
3. Do you/did you have a medical staff designation while serving in the military?
 - a. Yes
 - b. No
4. Have you ever been a prisoner of war or detainee?
 - a. Yes
 - b. No
5. Are you willing and able to participate in this study about your training and deployment history for CCC?
 - a. Yes, I consent to participation in this study.
 - b. No, I do **not** consent to participation in this study.

Demographics:

1. What is your rank?
2. What is your age?
3. Are you male or female?
4. What type of medical care provider are you?
 - a. Physician
 - i. Surgeon
 - ii. Non-surgeon
 - b. PA or other mid-level provider
 - c. Registered Nurse
 - d. Certified Registered Nurse Anesthetist

- e. Medic/Technician
 - f. Other _____
5. What is your specialty?
- a. General Surgeon
 - b. Trauma Surgeon
 - c. Other Surgeon
 - d. Emergency Physician
 - e. Other Physician
 - f. ER Nurse
 - g. OR Nurse
 - h. ICU Nurse
 - i. Other Nurse
 - j. OR Technician
 - k. Licensed Vocational Nurse
 - l. Respiratory Therapist
 - m. Other
6. How many years have you practiced in your specialty?
- a. < 3 years
 - b. 3-5 years
 - c. 5-10 years
 - d. >10 years

Deployment Information:

7. How many times have you deployed to a combat zone?
- a. 1 time
 - b. 2 times
 - c. 3 times
 - d. 4 times
 - e. 5 times
 - f. 5 times or more
8. How many years of service did you have at your first deployment?
- a. <1 year
 - b. 1-2 years
 - c. 2-3 years
 - d. 4-6 years
 - e. >6 years
9. To what Role/Level of Care were you deployed?
- a. Role/Level 2 (FST, FST+, FST-)
 - b. Role/Level 3 (CSH, CSH-)
 - c. I have been deployed to both Role 2 and Role 3
 - d. Other (please specify)
10. If you were deployed or selected to deploy to a Role/Level 2 team, how were you selected?
(Please include volunteer participation.)
11. In your experience, were you trained to function at the R2 facility based on any multinational/multiservice standards?

- a. Yes
 - b. No
12. If you answered yes to the previous question, what specific type of training did you receive?
13. In your experience, were you evaluated for competency to function at a R2 facility?
- a. Yes
 - b. No
14. If you answered yes to the previous question, how was competency evaluated? To your knowledge, was it based on any multinational/multiservice standards?
15. In your opinion, what is the optimal team composition for R2 teams? By specialty and number of personnel.
16. In your opinion, what effect, if any, does team composition have on split operations?
17. Please list the name of location and timeframe for your first five deployments.
- a. Location/Date/Duration
 - b. Location/Date/Duration
 - c. Location/Date/Duration
 - d. Location/Date/Duration
 - e. Location/Date/Duration
18. Which deployment(s) did you receive individual training? Please select all that apply, if applicable.
- a. First deployment
 - b. Second deployment
 - c. Third deployment
 - d. Fourth deployment
 - e. Fifth deployment
 - f. Additional deployment (Please specify):

Pre-deployment Training:

19. What pre-deployment training did you attend prior to your *first* deployment (you may choose more than one option)
20. Did you receive individual pre-deployment training in any of the following general areas? Select all that apply.
- a. Role specificity
 - b. Operations/logistics
 - c. Personal safety and injury prevention
 - d. Training for personal recovery
 - e. Preparation for traumatic experiences
21. Did you receive individual pre-deployment training in any of the following specific areas? Select all that apply.
- a. Your Skill Set
 - b. Equipment Familiarization
 - c. Hemorrhage
 - d. Resuscitation
 - e. Burns
 - f. Trauma
 - g. Palliative Care

- h. Orthopedics
 - i. Pediatrics
 - j. "Damage Control" surgery/resuscitation
 - k. Continuity of Care familiarization or consideration (treatment implications for each Role level)
 - l. Resiliency
 - m. Cultural Awareness
 - n. Joint Operations
22. If you did not receive individual pre-deployment training in any of the specific areas, what was the reason? Select all that apply.
- a. No available resource
 - b. Time constraints
 - c. Scheduling
 - d. Other (please specify)
23. Based on your answers to the question above, please elaborate on the reason(s) for not receiving individual pre-deployment training.
24. What type of team-based pre-deployment training did you receive? (Please include general and specific areas if possible)
25. If you did not receive team-based pre-deployment training, what was the reason?
- a. No available resource
 - b. Time constraints
 - c. Scheduling
 - d. Other (please specify)
26. Based on your answers to the question above, please elaborate on the reason(s) for not receiving team pre-deployment training.
27. What type of pre-deployment sustainment training would you recommend?
28. How frequently do you think providers should receive sustainment training?
29. What type of pre-deployment refresher training would you recommend?
30. How frequently do you think providers should receive refresher training?
31. In your opinion, do you believe credentialing/privileging policies affected your ability to obtain trauma training?
- a. Yes
 - b. No
32. If you answered yes to the previous question, please explain.
33. Did you receive training in country?
- a. Yes
 - b. No
34. Did you receive sustainment training for CCC related team skills in country?
- a. Yes
 - b. No
35. If you answered yes to the previous question, please describe the sustainment training you received for CCC related team skills.
36. Did you receive refresher training for CCC related team skills in country?
- a. Yes

- b. No
- 37. If you answered yes to the previous question, please describe the refresher training you received for CCC related team skills.
- 38. Did you receive sustainment training for CCC related individual skills in country?
 - a. Yes
 - b. No
- 39. If you answered yes to the previous question, please describe the sustainment training you received for CCC related individual skills.
- 40. Did you receive refresher training for CCC related individual skills in country?
 - a. Yes
 - b. No

41. If you answered yes to the previous question, please describe the refresher training you received for CCC related individual skills.

Deployment Readiness:

- 42. For your initial deployment, on a scale of 1-10, how comfortable/confident did you feel in providing CCC?
- 43. For your initial deployment, on a scale from 1-10, how ready did you feel to provide CCC?
- 44. For your initial deployment, on a scale from 1-10, how prepared/well trained did you feel in your ability to provide CCC?
- 45. For your initial deployment, on a scale from 1-10, how well oriented were you:
 - a. To your new environment: 1-10
 - b. To equipment: 1-10
 - c. To personnel/team: 1-10
- 46. Based on your in country experience, was your pre-deployment training adequate?
- 47. In your opinion, what was the most valuable preparation/training received?
- 48. Based on your experience, what training would you have liked to receive to increase either your efficiency or effectiveness during deployment?
- 49. Based on your experience, what are the critical CCC skills necessary for medical providers?
- 50. Based on your experience, which skill sets did you employ the most?
- 51. Based on your experience, which of your skill sets did you feel were weak and/or could have benefited from additional training?
- 52. Based on your experience, what core trauma competencies or skill capabilities, if any, do you believe were missing from care team members rather consistently.
- 53. Based on your experience, do you believe that one group of care providers was seemingly and consistently better prepared for trauma care than other groups?
 - a. Yes
 - b. No
- 54. If so, what groups do you believe were better prepared and why?
- 55. Regarding available support: On a scale from 1-10, how much support did you feel was available to you when conducting R2 operations?
 - a. Command and Control: 1-10
 - b. Evacuation: 1-10
 - c. Logistics: 1-10
 - d. Personnel: 1-10

56. Have you experienced R2 underutilization, such as frequent over flights to a R3 facility, few casualties, etc.?
- a. Yes
 - b. No
57. If you answered yes to the previous question, please explain reasons why you experienced R2 underutilization.
58. To your knowledge, are there any inter-war training or sustainment programs in place for the Tri Services?
- a. Yes
 - b. No
59. If you answered yes to the previous question, please list/elaborate on the available programs.
60. Did you work with healthcare clinicians, techs or medical providers from any of our sister services?
- a. Yes
 - b. No
61. If yes, which services? On what type of platform?
62. Did you work directly with any of our NATO partners who are healthcare or medical/technical providers?
- a. Yes
 - b. No
63. Based on your experience, what are significant barriers to providing CCC for deployed medical personnel?
64. Please add any additional comments or recommendations that you care to make

Thank you for your time and consideration.